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THE ASSESSMENT THROUGH BACKWARD MASKING OF COGNITIVE PROCESSING CHARACTERISTICS IN THE LEFT AND RIGHT VISUAL FIELDS.

by

EDWARD GREENBLATT

A dissertation submitted to the Graduate Faculty
in Psychology in partial fulfillment of the
requirements for the degree of Doctor of Philosophy,
The City University of New York

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Abstract

THE ASSESSMENT THROUGH BACKWARD MASKING OF COGNITIVE PROCESSING CHARACTERISTICS IN THE LEFT AND RIGHT VISUAL FIELDS.

by

Edward Greenblatt

Adviser: Professor Jeffrey Rosen

A central backward masking procedure was used to determine cognitive differences between the right visual field (RVF) and the left visual field (LVF). Briefly, this technique involves the successive presentation of two briefly exposed stimuli. The first is the target (T) configuration, in this case letters which the S must identify. The second stimulus is the mask (M) which is made up of straight lines. Both the T and M are lateralized to a VF and spatially encompasses the same location. This technique permits temporal pattern assessment in performance (the number of letters correctly identified) as a function of increasing time delays between the T and M for the LVF and RVF.

In experiment I, the RVF performance was significantly better than the LVF (p<.01). In addition, the 13 intervals used between the onset of the T and the onset of the M, called the stimulus onset asynchrony (SOA), had a significant effect on the number of letter pairs that could be identified (p<.01). The SOA ranged from 0 to 120 msec in intervals of tens. Finally there was a marginal VF by SOA interaction (p<.067). The performance function for each VF contained significant linear, quadratic and cubic trend components. Maximum decrement in performance occurred sooner for LVF presented letters compared to the RVF presented letters. In addition, the decrement and improvement (or slope) in the quadratic component was found to be more gradual for the LVF. Thus vulnerability to the M encompassed a longer duration for LVF presented letters. These results suggest that the cognitive operations necessary in identifying letters are different for the two hemispheres. Although letter identification is superior for RVF presented letters, the initiation of a cognitive process commenced sooner for the LVF compared to the RVF.

Further assessment of processing differences between the hemispheres was thought possible by using a second M with a lower density level (or the ratio of darkened area encompassed by the lines, to the white background). If the processing characteristics were indeed different, then the second M should have a differential impact on the performance functions for the given hemisphere.

Results indicated that performance was significantly better for RVF presented letters, that SOA significantly affected performance and that there was a VF by SOA interaction, all replicating experiment I. In addition, the two masks had a differential affect on performance ($p<.01$). The three way interaction, M by VF by SOA, was also significant supporting the prediction that processing would be differentially affected by the change in M density.

Further analysis revealed that different trend components were significantly affected by the change in the M when the two VFs were compared. For both VFs the first half of the function was affected by the change in the M leaving the remaining half of the function primarily intact. Visual inspection suggests that the three way interaction was primarily the result of the change in the function for LVF presented letters. This was noted by a dramatic change in the period of vulnerability to the M. Decreasing the density decreased the vulnerability to the M as measured by performance.

Different models are discussed to account for the results in experiments I and II. They encompass issues related to interhemsipheric transfer time as well as qualitative differences in processing for the separate hemispheres. Finally, further research is discussed in order to investigate these differences more thoroughly.

This includes increasing the number of letters in the array as well as using different stimuli.

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Experimental analysis of the concept of information processing requires a detailed temporal analysis of the changes in pattern of performance. When applied to tachistoscopic investigation of differential information processing characteristics of the two cerebral hemispheres the temporal analysis has most commonly been embodied in some variation of a reaction time (RT) paradigm. Here the temporal dimension is expressed as the dependent variable and different processes, whether serial or parallel are inferred from different obtained slope characteristics.

While RT measures can generate a temporal pattern and afford greater operational specification of information processing than measures based on the number of correct identifications, RT itself is notoriously vulnerable to a variety of extraneous variations. Ideally one should be able to retain the precision of a temporal analysis while exercising greater control. One option, the one pursued here, involves the systematic use of the temporal dimension as an independent, rather than a dependent variable. The design employed effectively interfaced the backward masking procedure evolved by Turvey (1973), with tachistoscopic assessment of visual field asymmetries.

The paradigm used to investigate processing characteristics for the left and right hemisphere (LH and RH respectively) originated from earlier work with non-lateralized material. It is therefore advantageous to review some of these earlier works in order to better assess its application in research dealing with hemispheric specialization.

In these studies the S's task was to memorize a number of digits or letters (called elements). A digit or letter was then presented to the S. The S had to determine whether the digit or letter, which was called the probe, was a member of the set just memorized. For example, if the S memorized the set 2,4 7,8 and the probe digit was 6, he or she would respond in the negative. The set size, which was the number of elements memorized, was increased from 1 to sometimes 6 letters. RT measures were assessed for increases in set size. The underlying assumption was that if a linear function resulted when RT measures were plotted as a function of set size, then the mode of processing was serial. That is, the S had compared the probe to each memorized element sequentially. If on the other hand, Ss could compare the probe to all elements simultaneously, then processing had been parallel in nature and would be noted by a nonsignificant increase in RT as a function of increasing set size.

Sternberg (1966), utilized the above technique and found that each additional memorized digit resulted in an average increase in RT of 37.9 msec. This particular task required the S to memorize a set of digits (ranging from 1 to 6 digits) that were visually displayed one at a time. The stimulus probe was presented 2 sec after the presentation of the final memory set digit. Ss were required to report whether the test digit was contained in the stimulus set by pressing one of two levers, one lever for responding yes the other, no. Except for sets containing one digit the slopes of both the negative and positive responses were the same. The results suggested that processing is not only sequential, but that the scanning process of the stimulus set is exhaustive and not self-terminating. That is, the Ss scan the entire stimulus set regardless of whether the test digit occurred at the beginning or end of the stimulus set. If the scanning process were self-terminating the S would have stopped scanning the stimulus set as soon as the test digit was found (assuming the test stimulus was in the set). In the condition in which the test stimulus was one of the digits in the set, the position where it occurred in that set had been randomized with the restriction that it would occur at each position an equal number of times. Therefore, if the scanning process were self-terminating, the RT averaged over all positions for a given set size should approximate the RT for the middle digit in the stimulus set for positive responses. Therefore the slope of the positive responses would be half that of the negative responses. Since the slopes of the negative and positive responses were not significantly different, exhaustive, rather than self-terminating scanning was indicated.

Before investigating this technique further, it might be useful to evaluate its application with lateralized material. Research into hemispheric specialization has demonstrated that in general the LH is superior to the RH for verbal tasks and the RH is superior to the LH for non-verbal tasks (Geffen, Bradshaw & Wallace 1971, Rizzolatti, Umilta & Berlucchi 1971, and Klein 1976 to name just a few). However, processing characteristics (i.e. whether serial or parallel) for the left and right hemispheres are less well understood. This information could be obtained by applying Sternberg's procedure to lateralized stimuli.

Klatzky (1970) modified Sternberg's task in order to assess hemispheric processes. She had Ss name pictures prior to the experimental condition. The beginning letter of each picture named became the test stimulus. Letter sets (ranging from 2 to 5 letters) were centrally presented. This was followed by either a probe letter or a probe picture presented to the right visual field (RVF) or left visual field (LVF). Information presented to a specific visual field (VF) will project to the contralateral hemsiphere (Elliot 1969). Thus RVF presented stimuli will project to the LH and LVF presented stimuli to the RH. The Ss' task was to determine whether the letter or first letter of the named picture was in the preceding stimulus set. RT measures to a lever press were assessed for both negative and positive responses. As the stimulus set size increased RT increased in a linear fashion for both stimulus conditions (letters and pictures), hemispheres, and for both response conditions (negative and positive) as well.

The results are only suggestive with regard to identifying the nature of processing for the separate hemispheres. That is, the test stimuli were presented for 400 msec which exceeds the maximum duration for stimulus lateralization to occur (White 1969). In addition, be cause of the apparatus used, Ss were told to which VF the lateralized stimuli would be presented. Again, this decreased the likelihood that the stimului were lateralized to a specific hemisphere.

Cohen (1973) was also interested in identifying the cognitive process for the separate hemispheres when the stimuli are lateralized. The task was somewhat different from both that of Sternberg (1966) and Klatzky (1970) but the rationale for characterizing a process as serial or parallel using RT measures was the same.

Cohen (1973) presented an array of letters (varying from 2 to 4 letters) tachistoscopically to either the RVF or LVF. The S's task was to determine whether all the letters were the same. Cohen found that LH performance was significantly faster than RH perfromance in responding to the letter arrays that were the same. These results are consistent with the literature which reports LH superiority for letter recognition (Umilta, Frost & Hyman 1972, Rizzolatti, Umilta & Berlucchi 1971). More important however is that RT for positive responses increased significantly as a function of stimulus set size for the LH but not for the RH. The increase was linear and was approximately 40 msec for each additional letter in the array for the LH. The processing for the RVF-LH presentation fitted the serial processing model the best. The absence of an increase in RT as a function of the number of letters in the array for LVF-RH presentation suggests that processing was parallel.

For negative responses, RT did not differ across VFs. There was however a significant increase in RT as a function of set size. These results are consistent with Sternberg's (1966) results in which both negative and positive responses produced a linear function with increase in set size. The replicability of the results are remarkable in light of the fact that the paradigms are quite different. Essentially, Sternberg's task was a search for an element in a memorized set whereas Cohen's task required the S to make a same/different discrimination.

Egeth, Jonides & Wall (1972) used a task which was more similar to Cohen's (1973) with the exception that the stimuli were not lateralized. They found in contrast to Cohen that increases in the number of elements contained in the stimulus did not substantially increase RT for either the same or different responses. However, when Egeth et al.

(1972) changed the task from a same/different discrimination to a search paradigm, the results were less clear. Although the positive responses (presence of the target) were indicative of parlallel processing the absence of the target generated a function with a slope greater than zero. Although Egeth et al. stated that "slight slope ... (made the) data more difficult to interpret" (p. 686), the data also suggest that serial processing was operating. The contrasting results across researchers (i.e. Cohen vs. Egeth et al.) and even across experiments for a given researcher may have been a function of different strategies employed by the Ss. Ss, in all likelihood, are flexible enough to employ different strategies and in the course of the experiment adopt the most efficient strategy for the prescribed task. (An efficient strategy for the S may not necessarily coincide with the experimenter's conception of efficiency.) Strategy differences will be discussed later in relationship to hemipsheric specialization.

Cohen (1973) and to some extent Klatzky (1970) further examined processing characteristics in the two hemisheres. Cohen's results (in experiment I) suggested that processing is different for the two hemispheres for at least one type of response (same response). These findings support Levy-Agresti & Sperry's (1968) conceptualization of differential hemispheric processing. They found that in commissurotomized patients the RH operated in a parallel fashion for a task requiring matching of a 3-dimensional figure presented tactily to a 2-dimensional figure displayed visually, while the LH processed the information serially.

However, Cohen, in the same paper, demonstrated that changing the task from a verbal to a nonverbal encodeable task resulted in the LH no longer processing the material sequentially. (RT was not systematically affected when the set size was increased from 1 to 2 elements.) These results are intriguing since the constraints of the task seem to be more relevant than VF of presentation in determining the processing characteristics. In other words, in spite of LevyAgresti & Sperry's formulation of differential processing characteristics specific to a hemisphere, it might be the case that both hemispheres are able to process material serially or in parallel. The determinant of the process thus is related to the requirements of the task.

Evidence that the task rather than the hemisphere might determine the form of processing comes from a series of experiments by Seamon (1974). He found that by instructing S to use a particular strategy in memorizing a set, he could either increase RT linearly as set size increased, or keep RT constant across increasing set sizes.

The S's task was to determine whether a probe word was included in the set of words just memorized. Except for the elements being words instead of digits, the task was similar to Sternberg's. However, the strategy in rehearsal took three forms. Some Ss were told to just rehearse the words subvocally (non-imagery), others were told to generate separate images for each word (separate imagery) and still others were told to generate an image for each word in which the words were related pictorially (relational imagery). So, for example, if the set contained the three words dog, house and door, the non-imagery group would subvocally practice the three words. The separate imagery group would generate a picture for each word while the relational imagery group would generate a picture of a dog going through the door of a house.

When the probe was not lateralized, Seamons found that for both the non-imagery and separate imagery groups, RT increased as a function of set size. However, for the latter group RT remained the same as set size increased.

Seamon then used the latter strategy, i.e. relational imagery, in conjunction with lateralizing the probe to a VF. Although the probe was only lateralized 1 to 1.25 degrees from fixation, RT was significantly faster for the RH. Also, the results suggested that both hemispheres processed the information in parallel. That is, RT did not increase over set size for either the RH or LH. When the strategy was changed so that Ss were required to subvocalize each word, RT increased linearly as a function of increasing set size. However, the RH was still performing faster than the LH which is contrary to the assumption of LH superiority for verbal tasks. But the data do suggest that a particular type of processing is not necessarily restricted to a given hemisphere. Therefore Levy-Agresti & Sperry's (1968) characterization of a hemisphere as operating exclusively in one mode, may not be entirely correct. Rather, identifying the process for a given hemisphere with respect to a given task may be a more accurate way to describe hemispheric specialization.

The rsearch discussed thus far has been in terms of RT measures which help to implicate a particular cognitive processing strategy. However, the inference from such a measure may be questionable. According to Townsend (1971) a linear function is not convincing evidence for describing a process as serial in nature. In fact, parallel processing can generate a function which mimics a serial function. This would be possible if processing capacity were assumed to be finite. Then, increasing the number of elements might require a longer period of time to process the information even though the elements were processed simultaneously. Since increase in the number of elements in a set requires a longer time to process, the function would be linear and mimic a serial form of processing.

There is a more general criticism in inferring processing characterisitics from RT. RT can be conceived of as the end product of many stages, with each stage encompassing a particular process. It is questionable whether these stages can be separately identified using RT. (In the discussion of experiment I the assessment of processes within a given stage will be evaluated.) Sternberg (1975) believes that they can, and in fact identifies 4 stages required to decide whether a stimulus is included in a memory set. They are processing the probe, comparing it to the memory set, deciding on a yes or no response and emitting the response after its selection. Sternberg believes that the second stage, comparing the probe with the memory set can be separately assessed. When the RT is graphed as a function of the number of letters in the memory set, then the y-intercept (where set size on the x-axis equals zero) includes the time needed for all stages irrespective of comparison with the memory set. The RT function which is generated is extended to the y-intercept with the assumption that linearity is maintained. Since the y-intercept is defined as the point where x=0 and x equals the number of elements in the set, stage 2 is eliminated since the probe cannot be compared to a non-existent set. The second stage then, is represented by the slope of the function. The slope indicates the increase in time necessary to scan each additional element in the set.

Further support for a four-stage process is given by Sternberg's utilization of an additional factor effect which is an extension of Donder's subtractive method (Donder 1969 and Sternberg 1969b). Donder's subtractive method relies on the ability to develop a task which requires an additional stage compared to a prior task. The difference in RT for the two tasks is assumed to be a measure of the additional stages necessary to complete the second task. Two problems with this technique are the difficulty of developing a task which requires an additional stage, and the possiblity that the added RT difference is not unequivocally interpretable, i.e. it might result from an increase in RT for all processing stages.

Instead of developing a task in which another complete stage is required, Sternberg (1969b) proposed that variables be developed (called factors) to determine their influence on the stages in question. If different factors interfere with specific stages, then their contribution to the mean RT should be additive. If, however, a particular factor increased processing time in more than one stage, then an interaction would be present when two factors are used. If, for example, a memory set is varied and the test digit is also varied in legibility, then the increase in RT should be additive if each factor contributes an increase in processing time for a given stage. However, if stimulus legibility also increases scanning time, then an interaction should be observed. The converse is also believed to be true, if " 'additive factors' are discovered ... it is reasonable to believe that there exists a corresponding pair of stages, a and b ..." p. 282, (Sternberg 1969b).

Additional information can be gained when three factors are evaluated simultaneously. This helps discriminate between pairs of three factors interacting with pairs of stages and the case when all three factors interact with one particular stage. The latter case would result in a non-significant interaction.

Sternberg (1967) applied the additive effect technique to his task in order to determine the existence and independence of the first two stages. He presented either an intact or degraded probe. This was accomplished by embedding the probe in a checkerboard pattern. Memory set size was increased from 1 to 4 digits (excluding a 3-digit memory set) for the two conditions. If encoding and scanning are independent then the degraded stimulus condition should have increased the y-intercept without changing the slope of the function since the slope of the function (in which set size is plotted against RT) is believed to be dependent upon scanning only the memory set. However the y-intercept includes the time required to encode the test probe. Therefore, degrading the test probe should increase the y-intercept, according to Sternberg since more time would be required to identify the test probe.

Two sessions which included both the intact and degraded condition, demonstrated that the absolute increase in the y-intercept was greater than the slope increase for the degraded condition. The slope increase was significantly different for session 1 but not for session 2. The fact that there was a nonsignificant change in slope in session 2, and a significant increase in the y-intercept for both sessions suggest that the two stages, encoding and scanning, are distinct.

Sternberg (1969b, 1975), using data from his earlier work, further investigated a four stage model using the additive effect. The factors were stimulus quality, size of the positive set, response type (i.e. positive or negative), and the frequency of the response. The latter condition encompassed different chance probabilities that the response would be positive on a given trial. Most of the data came from his 1966 and 1967 publication. The results were plotted as a function of 2 factors averaged over the third. The functions would yield parallel lines if the effects were additive. A summary statement of the graphs are presented below. All functions were parallel, i.e. no interactions were significant.

1. RT plotted as a function of set size (1,2,4),for intact and degraded test stimuli.
2. Same set size as above, but plotted as a function of positive or negative response on RT.
3. RT plotted as a function of intact or degraded probe for negative and positive responses.
4. RT plotted as a function of response frequency for neg-

ative and positive responses.

5. RT plotted as a function of response frequency for the above set sizes.

The above results, in addition to indicating a nonsignificant 3-way interaction, strongly suggested that a 4 stage model is required to account for the increase found in RT.

One limitation in the additive method is that it does not give any indication of the duration of these stages. The indirect measure (as discussed above) can only indicate the number of stages required.

A more basic problem in Sternberg's (1967) study was suggested by Theios, Smith, Haviland, Traupman & Moy (1973). Although an exhaustive scanning hypothesis adequately explained Sternberg's data, Theios et al, believes that the self-terminating hypothesis is just as viable. They believe that Sternberg's effects were confounded because the stimulus set size was not manipulated independently of stimulus probability. As the set size the S was required to memorize was increased, the probablility that each element in the set would be presented on any particular trial decreased. Therefore it is unclear whether the increase in RT resulted from the increase in the set size, or from the change in probability. Previous work (Biederman & Zackery 1970) has demonstrated the importance of probability with respect to RT. Theios et al. used a design similar to

Sternberg's (1967) except that they controlled for the possibility that an element in the memorized set decreased in probability as the set size increased. This was accomplished by contructing two sets, the memory set and the probe stimuli, which would be responded to in the negative. The first group of elements was called the target and the second the non-target. Each element in the target and non-target set were paired for different presentation probability. For example, if a target had a .15 chance of being presented, a non-target was given the same probability.

When RT was plotted as a function of set size (for 2 to 5 elements), a linear relationship was obtained thus replicating Sternberg's results. Theios et al. also found that all probability effects were significant for each set size (from 2 to 5 elements). There was no significant interaction between set size and probability. The signficant difference in RT as a function of changes in probability for both negative and positive responses seems to be more consistent with a self-terminating scanning model rather than an exhaustive scanning model. The latter would predict that all elements in the set would be scanned regardless of chance differences. Further support of a self-terminating model was a significant difference found between negative and positive responses.

Klatzky and Smith (1972) used a somewhat different technique to assess probability effects independent of set size. Instead of using a fixed memory set (as Theios et al. used), each trial commenced with a new set. In addition, there were unequal numbers of positive and negative elements, in this case letters, for each memory set (i.e. if there were 4 elements in a set, Klatzky and Smith did not necessarily have 4 negative elements). Instead, they presented a memory set which was either marked or unmarked. Marked sets included letters with either one or two asterisks above the letters. One asterisk above a letter told the S that the probability of that letter being the target was 40% for positive trials. Two asterisks indicated an 80% probability.

Although there were no significant differences between the 2 marked conditions, there was a significant difference in RT for increased set size as well as for unmarked vs. marked set. The latter indicated that stimulus probability could significantly contribute to the mean RT. Since the slopes of the above functions were not significantly different (for the markded vs. unmarked set) the probability differences did not affect the comparison stage. However, as set size increased from 4 to 5 elements RT declined for the positive responses. Whether this decrease is significant is unclear since Klatzky et al. described this decrement in terms of "departure from linearity." However, Klatzky et al suggests the departure from linearity results from the retrieval and decision processes operating in parallel. They suggest that with smaller set sizes the decision process commences after the scanning process. However, with larger set size the decision process commences before the scanning process terminates. Although it is quite possible that these stages are organized in a parallel manner, Klatzky et al. do not discuss what times the decision stage.

Another important finding of Klatzky and Smith is an order effect. For positive responses, RT was shorter for elements that appeared sooner in the memory set. This runs counter to what would be expected for an exhaustive comparison model. According to Baddeley & Russel (1973), the reason Sternberg did not get order effects is that a 2 sec delay period followed the presentation of the set be fore a probe was presented. This might have given the Ss enough time to rehearse and thus effectively eliminate an order effect.

The last difficulty which Sternberg's model cannot account for, is memory sets which contain a repeated item. According to Sternberg's model a repeated digit should not affect RT since all the elements in the set are scanned. However, Baddeley & Ecob (1973) found that when a digit was repeated RT was significantly shorter.

In summary, Sternberg's model is primarily based on RT differences reslting from specific manipulations. From these results a four stage model can only be inferred. More information could be obtained if time were not the simple and sole indicator of preceding cognitive events. This can be accomplished if the temporal dimension were under the control of the E, instead of being the response measure. The masking paradigm constitutes a situation in which time is the independent variable. A mask (M) can be presented at the same time as the target (T) or anytime after or before the T. Stimulus onset asynchrony (SOA) isthe interval between the onset of the T and the onset of the M. An SOA of zero is the condition in which the T and M are presented simultaneously. Masking thus permits interference with a cognitive operation at any point in time.

Masking encompasses many different conditions in which a T becomes degraded or completely disappears. An M can follow the T or precede the T. The terms reserved for these two conditions are backward and forward masking, respectively. A special condition in which the M and T do not spatially overlap is called metacontrast. This is one method used to investigate the time course necessary for the formation of contours (Werner 1935). Generally a disc is the T and the M is a ring. The size of the ring is just large enough for the disc to fit into the inside diameter of the ring. Three other types of masks used in masking experiments are light flashes which overlap the T spatially, arrays of dots randomly distributed, and dots or patterns which have either some order to them or contain some characteristics which make them similar to the T. The random mask is called a noise mask and the latter a pattern mask.

Kinsbourne and Warrington (1962a) assess the different parameters responsible for masking letter identification. These authors demonstrated that a noise mask must have at least the same luminance as the T for masking to occur. In addition, the interval between the termination of the T and the onset of the M, referred to as the interstimulus interval (ISI), is an important determinant of masking. The minimal interval necessary to evade masking is referred to as the critical ISI, and the minimal duration of the T to evade masking is called the critical T duration. According to Kinsbourne and Warrington (1962b) a relationship between the critical duration of the T and the ISI exists which could be expressed by the following function to account for evading an M. T duration x ISI = a constant. Turvey (1973) found that by varying intensity as well as T duration, T energy x ISI = a constant (K) more accurately described this relationship, where T energy is defined as the luminance of the T times its duration.

The process by which masking interferes with the identification of the T has largely been explained by 2 different theories. According to Sperling (1963, 1971) the M effectively terminates the processing of the T.

Kinsbourne and Warrington (1962a, 1962b) believe that the M impedes the identification of the T by not allowing the S to separate the two stimuli into two discrete events. The 2 conditions are popularly known as the interrruption and integration theories respectively. The distinction between the two theories is important since the locus of masking both cognitively and physiologically are thought to be quite different for each. The cognitive process which is required to identify a stimulus in all likelihood is being affected sooner if masking is the result of interruption rather than integration. As previously mentioned, masking resulting from integration is considered the failure to separate 2 cognitive events. Before an event can be cognitively processed the event itself has to be identified. Therefore masking through intergration would occur earlier than masking through interruption, since in the latter case a cognitive process already underway is effectively interrupted.

Turvey (1973) as will be discussed in more detail later, identifies two types of masking. One type, which effectively masks the stimuli when both the T and M are presented to the same eye (monoptic presentation) is called peripheral masking. The other type, central masking, can occur even when the T is presented to one eye and the M to the other. The latter type of masking has been associated with the integration theory and the former with the interruption theory.

Early research concentrated on demonstrating the importance of one theory at the expense of the other. Colheart & Arthur's (1972) work suggests that masking occurs through the integration of two discrete stimulus events. They used two different masks, one which was made up of regular squares the other of random squares. Prior to the experiment, Colheart and Arthur demonstrated that if the masks were used as a background for the T letters, the letters were then more difficult to read when superimposed on the random squares. Therefore, if the integration theory correctly described the process of masking, the random squares should lead to a more dramatic decrement in performance than the regular squares. However, if masking is the result of interruption there should be no significant difference in performance between the two conditions. The underlying assumption for these predictions, according to Colheart and Arthur, is that if masking is the result of an interruption, then both types of masks should be equally effective (assuming they are eqjivalent in all other parameters except for the organization of the squares). This is because the effect of the M only results in the termination of an ongoing cognitive process. In contrast, the integration model would predict dissimilar performances since the T is more difficult to identify on a random than on a regular squared background and thus would facilitate an integration of the T and M when the random M was used. The results showed that performance was most affected by the random M, which apparently supported the integration theory.

Schiller (1968) investigated masking on the cellular level. Although the focus of his attention was on determining whether backward and forward masking were similar phenomena, he did find 2 distinctive single unit discharge characteristics in backward masking. He analyzed backward masking in cats by recording from the lateral geniculate nucleus (LGN). For both the T and M, he used discs of lights varying both in intensity and ISI. He found that the LGN will respond to two flashes if the events are spaced sufficiently apart. However, if the ISI is less than 50 msec., and the second flash is greater in intensity than the first, the response to the first stimulus does not occur. Although there were 2 discrete stimulus events, the LGN only responded to the second. If the two flashes were of equal intensity then partial summation took place at an ISI of 35 to 50 msec. The latter phenomena suggest that the two events are no longer discrete and thus effectively supports the integration theory. Keeping in mind that the T and M were discs of light, it is unlikely that the previous findings (in which only the second stimulus elicited a response) resulted from a disruption of a cognitive process.

Both Schiller's and Colheart's work suggest that masking occu through the integration of two discrete stimulus events.

However, the interval between the T and M was zero in Colheart's work, and 50 msec in Schiller's work. These intervals and other important parameters will be discussed below in an effort to show that masking may operate through more than 1 process.

Liss (1968) was also interested in determining the nature of the process mediating masking. Using 3 different conditions, backward masking, concurrent masking and no masking, he determined that backward masking stops the processing of the stimulus, thus supporting the interruption theory. The task required the identification of 1, 2, and 4 letters. The M was 3 rows of the letters N and O which completely overlapped each other. In the backward masking condition the T durations were 30, 40, 50 and 70 msec and were followed by the M at an ISI of zero. In the concurrent masking task the stimuli were presented at the same time as the M and for the same duration (100 msec.). The luminance ratio was varied between the T and M with the T intensity always more than the M. Finally, in the no M conditon the stimulus was presented for 7 and 9 msec. The results demonstrated that concurrent masking is more similar to the no masking condition as measured by mean number of letters correctly identified for the 1, 2, and 4 letter arrays. Decrement in performance was greater for the backward masking condition. Liss assumed that masking degrades the stimulus in the concurrent masking condition without affecting the "processing time". He reasoned that in backward masking the M impedes the identification of the T differently than in the concurrent masking and therefore is not the result of a degraded image. He did not take this as strong evidence that backward masking operates through interruption, but only suggests it as a possibility. "Even if we accept the view that backward masking stops stimulus processing, it is still not clear at what stage the disruption occurs" p. 329. This conclusion is not very convincing since the absence of integration may not leave interruption as the only theoretical alternative (an arguement equally applicable to Colheart and Arthur's position). However, Liss' experiment was important in two ways. First, he introduced the possibility that more than one type of masking was possible and second, he demonstrated qualitative differences in the perception of the T for the three different conditions. In the second part of the experiment Ss judged the brightness, contrast, sharpness, etc. in all three conditions. The differences in the Ss' judgements gave converging evidence of different types of masking. "... With the effective mask, the stimulus seems to disappear just as the mask appears while with the less disruptive mask, the stimulus typically appears through the mask" p. 330. Furthermore, Liss gives anecdotal results concerning the parameters which seem to contribute to masking (i.e. line thickness) and adds that "it appears that backward masking stops stimulus processing whenever the spatial analysis of both the stimulus and the mask requires the use of the same central mechanism" p. 330.

The importance of qualitative differences in masking were further developed by Turvey (1973). He tried to replicate Kinsbourne and Warrington's (1962a, 1962b) finding that masking results whether the T and the M were monoptically presented or alternatively dichoptically presented. Turvey was only able to demonstrate the effect when the T and M were presented monoptically using a random M. However, dichoptic masking occurred when a pattern M was used instead of a random M. He found that the relationship that existed for a random M (T energy x ISI=K) no longer applied. The critical T duration, the minimal duration necessary tio evade the M, was now contingent on stimulus asychrony (SOA). SOA is defined as the time between the onset of the T and the onset of the M and therefore can be redefined as T duration plus the interstimulus interval. A function to describe the minimal T duration necessary to evade masking then, would be critical T duration = T duration + critical ISI = K. The parameters that Kinsbourne and Warrington described as necessary to obtain masking no longer applied. Masking was still possible using a pattern M, even if the energy level of the T was greater than the M. Also masking was independent of T duration which would be expected, since the energy level of the T is dependent upon the T duration, and the energy level was no longer a relevant parameter.

The distinction between the two types of masking was further delineated by establishing critical T duration (necessary to evade masking) as a function of pattern M duration for monoptic presentation. As the pattern M duration increased from 2 to 25 msec, T duration was found to increase in order to evade the pattern M. However after the pattern M was increased to 25 msec, no further increases in the pattern M required any appreciable increase in the T duration to evade the M. In addition, an abrupt change in the function when pattern mask duration increased from 10 to 25 msec was noted. Error rates for reporting the T (a letter trigram) were different for the range of pattern M durations of 1 to 10 msec as compared to 25 to 500 msec. For the shorter durations the error rate was evenly distributed throughout the trigram whereas the error rate for longer M durations was dependent on position of the letters within the 3 letter display. In addition the subjects' experiences were quite different. For the shorter M durations the Ss reported that T was "...'messy', 'mixed up', 'hard to make out', and 'unclear'," as compared to "...'pattern stopped me reading the letters', 'pattern replaced letters', 'image of letters shortened by pattern'" for the longer mask durations.

And finally by monoptically presenting a pattern M at a constant duration he found that the required ISI (or critical ISI) necessary to evade an M was determined by the multiplicative function (T energy x ISI = K) for T durations of 2 and 3 msec. Thereafter for increases in T duration, the function was contingent on SOA and was therefore determined by the additive function (T duration + ISI = K).

The fact that masking by noise yields a different function compared to a pattern M, different parameters govern masking with a random M compared to a pattern M and that subjective experience for the 2 masks seem to be quite different, suggest that the two types of masking are different processes. In addition, the fact that masking occurs only monoptically when a random M is used, but dichoptic masking is possible with a pattern M, not only lends support to the possibility that two different processes are being affected, but strongly implicates the former type of masking as a peripheral event and the latter as a central event. That is, since monoptic but not dichoptic masking is possible using a random M, the interfering effect on performance must be prior to the lateral geniculate nucleus where information from the two eyes cross over and synapse for the first time.

Turvey investigated another distinction between the two types of masking. He assessed performance in letter identification as a function of SOA values of 0 to 180 msec. To ensure central masking the enrgergy of the M was half that of the T. A U-shaped function was obtained when the number of letters correctly identified in the trigram was plotted against SOA. That is, performance level was poorest not for an SOA of 0 msec, but rather for an intermediate value of 48 msec. Turvey included another condition in which the M was twice as great in luminosity as the T. A monoptic function was obtained. In this condition performance increased as the interval between the T and M increased. The above experiment demonstrated that peripheral and central masking is maximal when the interval between the T and M is small. In the central masking condition, correct letter identification first declines as the interval between the T and M increases, and then improves again over time. For peripheral masking, no letters are identified correctly for the interval between 0 and 16 msec. However, the decrement in performance for the central masking condition never reached zero.

The differentiation between peripheral and central masking can now be understood as including the interruption and integration theories. As mentioned above, Turvey found that a U-shaped function was obtained for central masking. It is therefore evident that optimal masking in the central masking condition occurs well after the T has terminated and could not be the result of the M being superimposed on the T. Instead, the effect suggests that the M has a disruptive influence on the process of synthesis and consolidation of the T. In this context the slope of the negative component of the U can be taken as an index of the onset of the critical phase of consolidation. the extent of the trough can be viewed as a measure of the duration of this phase, while the depth of the U reflects the amount of disruption. Such an interpretation would identify central masking as defined by the interruption theory. In contrast to central masking, peripheral masking was found to be less effective, as indicated by better performance with increases in the interval between the T and M. Schiller's (1968) work, as well as pilot work in our laboratory indicated that peripheral masking may operate through integration. However the integration may take two forms. The first is when the M intensity is greater than the T and the ISI is sufficiently short, in which case recording from the LGN indicated that only the second flash (or M) is perceived. Phenomenological reports from human Ss in a pilot study conducted in our laboratory corroborates Schiller's findings. When the M was twice the luminosity of the T, thus ensuring peripheral masking and the ISI was sufficiently short, the S reported seeing only the M. (The T in this case was not a light flash but letters.) Both a pattern and random M gave similar results provided that the luminosity of the M was greater than the T. It is important to emphasize that the Ss did not have difficulty in identifying the masked letters because the letters and M were an integrated image, but rather, the presentation of the T letters were never perceived. Second Schiller also found that partial summation would occur provided that the luminosity was the same for the T and M and the M followed the T in the range of 25 to 50 msec. The experiment demonstrated that masking can be accomplished by the integration of two events up to a specific ISI. In addition, peripheral masking through integration seems to be an event occuring at or before the LGN.

As mentioned before, Colheart seemed to show that the integration theory, and not the interrruption theory described the process by which masking occurs. However, Colheart only used an ISI of zero instead of many different intervals. Since Colheart used two different masks (i.e. a pattern and a random M), with only one ISI, his conclusion was premature. As stated above, performance was the poorest for an ISI of zero (Turvey 1973) when masking was peripheral. If Colheart had used a number of different intervals between the T and M, instead of just one, he might have found that the pattern M could disrupt the identification fo the T by almost the same magnitude as the random M, for a particular ISI. Although Colheart is correct in stating that masking can occur by integration, this does not rule out the possiblity that masking can also result as a function of a disruption in a cognitive process, i.e. operate via interruption.

The above experiments demonstrate that masking can occur by both an integration of the T and M or by an interruption of the cognitive process the S is using to identify the T. The difference between the two types of masking have been called peripheral and central masking. Each type of masking is contingent on different parameters and yields a different function when performance is plotted against ISI.

Another difference between peripheral and central masking is the availability of letters when the T is displayed. That is, are all letters seen together or in temporal sequence? Kinsbourne and Warrington (1962a) found that increasing the T from one to three letters did not increase the critical ISI or the critical stimulus dura tion when a random M was used. Critical T duration was approximately 2.5 msec for all letters making up the array. The data therefore suggest that all letters became available at approximately the same time.

Sperling (1973), using a pattern M made up of letter fragments, found that increasing the T duration and keeping the ISI at zero increased the number of letters that became available. In fact, a letter became available every 10 msec.

Turvey (1973) found that when a pattern M followed a trigram, errors were equally distributed across the three letters when the range of the M duration was between 1 and 10 msec. For M durations between 25 and 500 msec., errors were unequally distributed across the trigram. There was a greater chance of an error occurring for the last letter in the trigram compared to the first letter.

The two groups of M durations showing different distributions of errors was found to be a function of the type of masking i.e. peripheral or central. Turvey, in the next experiment, determined T threshold levels (defined as the minimal T duration necessary to evade masking) at different M durations for three different ratios of T and M luminosity. When the critical T durations (thresholds necessary to evade masking) were plotted against pattern M durations, all three curves were found to asymptote after the M duration was increased above 35 msec. This indicates that increasing the M duration above 35 msec has a negligible affect on identifying the T. But increasing the duration of the M increases its energy level. Therefore the critical T duration is no longer affected by energy level, thus demonstrating that masking is accomplished by peripheral processes at the shorter M durations, and by central processes at the longer durations. Since Kinsbourne and Warrington used a random M, the ISI was not affected by increasing the number of letters in the T. But using a pattern M, Sperling was able to show that increasing the T duration increases the number of letters reported.

Kinsbourne and Warrington's work at first seems to suggest that letters became available all at once which implies that parallel processing is taking place. But masking was accomplished peripherally, thus making it unlikely that a cognitive operation was being disrupted. Instead, in all likelihood, the Ss never perceived the T, consistent with the phenomenological reports from our Ss in the pilot study.

Weisstein (1966), using a backward masking paradigm, assessed the cognitive processing of letter identification. She found that the cognitive process could not be described as either parallel or sequential. In the first of 2 experiments, the S was required to identify a letter which was surrounded by a ring. From previous research it was known that a ring can mask letters (Averbach & Coriell 1961). The letters that Weisstein used were either D or O. The visual display comprised 1 or 4 of these letters. The presentation of the ring was varied from 10 to 100 msec. One additional ISI was included in which the T was presented 20 msec after the M.

The number of errors was plotted for the 1 or 4 letter displayed separately as a function of ISI. Errors were greater over the whole function for letter arrays containing 4 letters. The maximum masking, defined as the most errors for any particular ISI, was 20 msec for letter displays containing one letter and 60 msec for the 4 letter display.

Overall error rates were consistently greater for the 4 letter display compared to the 1 letter display. A proportion of the maximum errors for a 20 msec interval to the total number of errors was assessed for each function. A proportion allows a comparison of the width or range of maximum masking to be compared among functions without the confounding of amplitude (of errors). It was found that the range of masking for the 4 letter display was significantly greater than the 1 letter display. If letter identification was strictly processed in a parallel manner, then increasing the letter display from 1 to 4 letters should not increase the width of the masking function. Since the width was 1.54 times as great for the 4 letter display as compared to the 1 letter display the processing was not parallel. However the processing was not serial either, since the width of the maximum range of masking was not 4 times as great for the 4 letter display.

A second experiment in which letter array size was varied (1, 2, 4 and 8 letters) gave similar results. Parallel processing was not indicated since there was an increase in the range of masking with increasing arrays. However the process was not serial either, since the width of the function was not a multiple of the number of letters in the display.

Although this method of assessing the kind of processing a subject utilizes is unique, the task required of the S may have contributed to the difficulty in determining how the information was processed. In the first experiment the only letters used were an O and a D in addition to a condition in which a blank was used. The second experiment used O and D only. Although Weisstein does not state why O and D were chosen as T letters, these letters are more similar to the masking ring and therefore would be more susceptible to masking in a metacontrast paradigm.

The identification of the letters by the S was probably approached differently than in the more traditional tasks of letter identification.

There is a likelihood that the S experienced the masking as qualitatively different when the T was D as compared to O. Kahneman (1968) indicates that similar parameters are responsible for apparent motion as are responsible for metacontrast masking (i.e. SOA). It is therefore likely that an S experienced a D surrounded by a ring differently from the way an O surrounded by a ring was. The S may therefore not actually identify the letter but rather use qualitative differences in masking in order to identify the T as either a D or an O. This becomes more probable in light of the fact that Ss were trained for eight to ten hours before the experiment.

Few experiments have utilized a backward masking paradigm as a technique to assess hemispheric specialization. One exception is McKeever (1972). She presented a letter to each visual half field (VHF) followed either .1 msec or 100 msec later by another pair of letters.

The following stimulus letters (FSL) were considered the M. The Ss' task was to identify as many letters as possible. Righthanded Ss identified more T letters (initial letters) in the RVF for the 100 msec ISI condition and more FSL were identified in the RVF for the .1 msec ISI condition. For the lefthanded Ss, significantly more T letters were identified in the LVF for both ISI conditions.

Some problems with the study were that only two ISI were used, the luminosity was not specified, and finally, a distinction between backward and forward masking was not clear. However it was one of the few laterality studies which incorporated this technique to determine different functioning characteristics for the right and left hemispheres.

The present research modified Turvey's paradigm in that letters were lateralized to a VF. Since it appears that masking can exert its influence centrally, it seemed reasonable to lateralize the T and M and in so doing ascertain whether masking would have a differential influence on right and left hemispheric stimulus processing characteristics. Specifically, would the 2 functions for the separate VF's generate a U-shaped function and if so, would they be similar in extent, phase and depth. To ensure central masking a pattern M was presented at half the luminosity of the T. Any decrement in performance throughout the function would thus strongly suggest that a cognitive operation has been disrupted.

Experiment I

Method

Subjects. Ss were 11 right-handed graduate and undergraduate students from City College of New York. For all Ss English was their native language. Ss were either paid $2 or received credit in their introductory psychology course. All Ss had normal vision or corrected normal vision.

Stimuli

Target. Each stimulus card or target contained two consonant letters either at the center of the card or lateralized 2 1/2 degrees either to the right or left of the center of the card and from the center of the letter. The two letters were vertically displayed and subtended a visual angle of .58 degrees horizontally by 1.73 degrees vertically. The space between the letters subtended a visual angle of approximately .46 degrees.

The deck of cards consisted of 65 different pairs of letters duplicated three times so that each pair appeared once in each visual field. The letter pairs included all letters except for all the vowels and the letters "J" and "Q". There were a total of 195 cards. Letraset letters were used. The size and style of the letters were 36 point Helvetica meduim.

Mask. There were 195 cards of which 130 were a pattern mask. The remaining cards were blank (see below for reason). Sixty-five cards had a mask in the RVF and 65 cards had a mask in the LVF. Each mask was made up of straight lines having the same thickness as the letter. The array of lines looked similar to the pattern mask that Turvey (1973) used. The only modification was that the mask covered the letter pair instead of having a mask for each separate letter. The density of the pattern mask, defined as the ratio of darkened lines to unlined area, comprised 37% of the area. The mask subtended a visual angle of 1.39 degress horizontally by 2.31 degress vertically.

Apparatus. A Gerbrands 3 channel tachistoscope was used to present the target and mask. The luminance was 4 and 2 footlamberts respectively. The luminance of the fixation point was approximately 0.3 footlamberts.

Procedure. The following instructions were read to the Ss while dark adapting.

> This is a study that examines visual perception of letters. You will be shown letters in this instrument. Please look into it. As you can see it's very dark. Your eyes will need a chance to get used to it. Be sure to place your face flat against the edge of this support.
>
> Once your eyes get used to the dark you may be able to see an outline of a grayish rectangle. If you do not see it by the end of 5 minutes we will start anyway.
>
> (Turn on fixation field) Now you see in front of you a picture of lines coming together on a white background. Please look at the gap in the center of these lines and try to imagine the point where all the lines would come together. Now try to look directly at that imaginary point. This imaginary point is called the fixation point and tells you where to focus your eyes. It's very important that you try to look at this imaginary point in

> order to clearly see the letters which will follow.
>
> During the experiment this fixation point will be on for approximately 1 1/2 seconds. As soon as it disappears (turn off fixation) it will be followed by two letters (turn on field 2) either in the center or on the left or right side of the card, like the one you see before you now. To make sure you understand the instruction at this point would you tell me the letters that you see. Please report the letters in order.
>
> During the experiment it is important that you resond as quickly as you can. However, it is also important that you report the letters correctly. Therefore do not sacrifice accuracy for speed. Are there any questions?
>
> We will now start the experiment. Before seeing the fixation card, the picture with the lines coming together, I will say READY. Remember to stare directly at the point where the lines would come together if they were continued. READY.

Each S was presented with 5 pairs of letters to each VF and at fixation. These 15 trials constituted a block of trials. The S was permitted to make one mistake in identifying the letters. The mistake could be either at fixation or in an VF. If the S made more than one mistake a second block of trials was run. If more than one mistake was made again the S was discontinued from the study. The letter pairs used in these training trials were made up of different letters from the ones used in the experiment.

The Ss were then told:

> You will again see a fixation card (display) followed by a pair of letters (display). However, a card with lines will now follow the pair of letters. The card will look like this (display mask). Ignore the lines and report the letters. Again report the letters in order.
>
> There will be times when the letters will be difficult to identify. If you are not sure of the letters you saw please guess. READY.

Ss went through the entire experiment with two 5 minute rest periods. For the experimental trials, Ss saw a fixation point for 1 1/2 seconds (see instructions above). At the termination of the fixation point the letter pairs were presented for 6 msec. The mask went on simultaneously with the lateralized letters or following a delay. A blank card and not a mask followed the letters presented at fixation. These letters were presented only to control for attentional difficulty and to decrease the degree of frustration the Ss might experience with the more difficult blocks of trials. The delay, measured as the time from the onset of the T, ranged from 0 to 120 msec. The mask duration was 6 msec and occupied the same space as the T that had been presented. Training trials were similar to the experimental trials (except for the absence of a mask in the remaining trials).

The 195 target cards were randomly presented with the constraint that within each block of 15 trials 5 cards were presented to each VF and at fixation. An additional constraint was that no more than two targets were consecutively presented to the same position and that within a given block of trials all pairs were different.

The 13 different SOAs with each one defining a given block of trials were arranged the same way for each S. The most extreme SOAs not already used were presented. That is, the order was 0, 120, 10, 110, 20, 100, 30, 90, 40, 80, 50, 70 and 60 msec.

Results

An analysis of variance for a repeated measure design was done. The independent variables were VF and SOA and the dependent measure was the number of letters correctly identified. Both main effects were significant (VF and SOA). See table 1. The means collapsed over SOA were 7.48 and 6.78 for the RVF and LVF respectively. The results were consistent with past research showing RVF superiority for letter identification.

Table 2 has been included in order to establish the SOAs which most likely contributed to the main effect of SOA. The percents for each SOA for the left and right VF, and the combined VFs represented the degree of change in performance over SOA compared to the overall performance across all SOA points. Essentially a grand mean is obtained which disregards SOA. This mean is considered baseline performance. Performance for each SOA is then expressed as a percent score of the squared deviation. The greater the percent for a particular SOA point the greater its deviation from baseline and thus expresses the degree it contributes to the main effect of SOA. The percents, however, do not indicate whether performance has increased or decreased. Therefore the means have been included in table 3.

For the combined VF the greatest percent change occured at 30 and 40 and then at 100-120 msec. Table 3 indicates that at 30 and 40 msec performance was the lowest and at 100-120 msec the highest. The significant main effect (of SOA) then was largely the result of these five SOA points.

The percent for the separate VFs across SOA in table 3 is best understood in context with the VF by SOA interaction. Table 1 indicates that the interaction just missed significance (p=.067). It therefore is of interest to determine whether the change in SOA had a somewhat different affect on each VF. Table 3 indicates that the greatest change occured at 20 and 30 msec in the LVF. In the RVF the greatest change occured at 40 msec. Another difference occurs at the last three SOA points. In the LVF the percent change occurs at 110 msec when compared to the adjacent points. This will be discussed later with respect to a posteriori comparisons.

In figure 1 the performance level for the separate VFs was plotted as a function of SOA. In the RVF maximum masking occurs at 40 msec. Maximum masking is defined as the SOA which yields the poorest performance. The performance at 40 msec is significantly different from 50 msec but not 30 msec as measured by the Duncan's New Multiple Range Test (see table 4). However the decrement in performance from 20 to 40 msec is significant. In addition the decrement between 20 and 30 msec is also significant. Figure 1 as well as table 4 indicate that decrement to masking commences at 20 msec and improves again after 40 msec. Rebound to masking occurs at 50 msec as measured by a nonsignificant difference between the performance level at 20 and 50 msec. Table 4 indicates that all adjacent points after 50 msec are not significant. This indicates a gradual improvement in performance up until 100 msec after which the function asymptotes.

In the LVF maximum masking occurs at 30 msec which is 10 msec sooner than RVF presentation. Eight of the eleven Ss showed maximum masking occuring sooner in the LVF compared to the RVF. Of the remaining Ss, two showed the reverse and one S showed maximum masking occuring at the same time for the two VFs. Performance level at 30 msec is significantly different from 0 and 60 msec as measured by the Duncan's New Multiple Range Test. However performance at 30 msec is not significantly different from either 20 or 40 msec. Other adjacent points which are not significantly different are 0-10, 20-30, 30-40, 40-50 and 50-60 msec. (See table 5.) This indicates that both the decline and improvement in performance are gradual for LVF presentation. Specificially, the decline in performance commences at 0 msec and terminates at 30 msec after which there is a steady improvement up until 60 msec. Performance is exactly the same for 70 msec as 60 msec. The gradual change is especially convincing when compared to the RVF. Both the decline and improvement in performance occur all within the SOA points of 20 and 50 msec for RVF presentation.

The degree of change is an indirect measure of the width or period vulnerable to masking. The slower the change in both (the decline and improvement) the greater the width or period. Therefore since the change in performance is more gradual for LVF presentation the greater is its width. In fact, the width can be described as encompassing the SOA points from 0 to 60 msec for LVF presentation and only from 20 to 50 msec fr RVF presentation. The width is therefore 60 and 30 msec in duration for the LVF and RVF respectively.

As previously mentioned, improvement after 60 msec is gradual and steady for the RVF. In the LVF, there is a dramatic improvement between 70 and 80 msec which is significant as measured by the Duncan's New Multiple Range Test. In figure 1 a drop in performance occurs at 110 msec. A posteriori comparisons demontrate that this decrement is not significant when compared to performance at 100 and 120 msec. However, a noticable percent change occured at this point and therefore count of the number of Ss showing at least a one letter decrement for the 110 msec interval as compared to both the 100 and 120 msec interval was assessed. Seven of the eleven Ss showed this effect.

A test for trends was done for each VF separately. This type of analysis would give additional information as to the equation(s) which would best describe the functions representing the performance level across the SOA points for each field. For both VFs there as a significant linear, quadratic and cubic trend component. In addition, the linear trend accounted for the majority of the variance for each VF. See table 6. The total variance accounted for by the three trend components are 87.55% in the LVF and 90.29% in the RVF.

To summarize the results, differences between VFs include an overall superior performance in the RVF compared to the LVF. Maximum masking occurs earlier in the LVF than the RVF and the rebound affect from maximum masking is more gradual in the LVF. Vulnerability to masking, as measured by the width of the "U" is greater for the LVF. And finally, three trend components were found to be significant for both VFs.

Discussion

A U-shaped function did not adequately describe the functions when the stimuli were lateralized in contrast to the results obtained by Turvey (1973). Although Turvey did not evaluate his data for trends, visual inspection of his graph suggests that a quadratic trend would account for the majority of the variance between 0 and 120 msec. The data for lateralized visual stimuli, in contrast to Turvey's foveally presented stimuli, indicates a linear and cubic trend in addition to the quadratic trend.

The assumption underlying these functions is that the mask disrupts a process in the consolidation of an ongoing analysis of the stimulus. Thus the "U" shape represents a period in time when a process necessary in the identification of the stimulus has been interfered with. The period of the "U" is an index of the duration of that process or at least the duration of that process which is still vulnerable to masking. The functions suggest that stimulus processing occurs sooner in the LVF than in the RVF and that a longer period exists for LVF presentation. This is based on the findings that maximum masking occurred sooner in the LVF and that the slopes describing the "U" were more gradual compared to RVF presentation. Also, there is a likelihood that an additional cognitive operation is necessary in the identification of the stimulus when presented to the LVF. This is suggested by the slight non-significant a posteriori comparison at 110 msec. This may be the result of a decreased vulnerability to masking which identifies this process.

Rationale for Experiment II

From Experiment I it is unclear as to whether the two VFs are best described as embodying a single process or whether more than one process is involved. This is especially relevant for the Ss that demonstrated a second point which was vulnerable to the mask (at 110 msec). Although the number of processes responsible for letter identification is relevant for all Ss, assessing the data to answer this question is somewhat different for Ss showing a second decrement and those that do not. Processing characteristics will be discussed first for those Ss showing a second decrement followed by all Ss in general.

Since a process has a beginning and end, it is possible that the decrement in performance at 110 msec in the LVF for the seven Ss is only another characteristic of the same process. That is, the properties which identify the processing characteristics for the initial decrement in the performance function may be similar for the secondary decrement. If this was indeed the case then any parameter change which affects the initial decrement would be expected to change the secondary component in a similar fashion.

Structurally different masks are known to produce differential patterns of performance (Kinsbourne & Warrington 1962a, 1962b and Sperling 1963, 1964, 1967). Previous work had concentrated on differences between random masks, pattern masks and light flashes. It was thought that by varying the pattern mask it might be possible to determine whether the process inferred from the initial decrement was also reflected in the second component.

The pattern mask was varied by changing its density, where density is defined by the ratio of darkened lines to unlined area. Thus Ss showing a decrement in performance at 110 msec in the LVF, when a similar mask is used as in experiment I will be compared to a second mask condition. If the two decrements in performance are the result of similar type of processing characteristics then any change noted in the initial decrement should also be present for the secondary decrements.

The analysis for all Ss will primarily consist of comparing the trend components for the different mask conditions in order to determine the processing characteristics for the separate VFs. If, for example, a change in one trend component is noted (for a given VF) which is defined as the variance of a particular trend accounting for the function, but the remaining trends are left intact as mask density is varied then the performance function most likely reflects different types of processes. Convergent evidence would primarily be based on visual inspection of the graphed function. A change in only one trend might be reflected by a change in only that part of the function which would most likely correspond to that trend leaving the remaining function intact. The change may be reflected by an increase or decrease in vulnerability to the mask density by a more shallow trough, a decrease period, or a change in slope. All or a combination of these changes may occur.

Hypothesis

From experiment I and previous studies in laterality a RVF-LH superiority in letter identification should occur. Also, the independent variable of SOA should again affect performance. The three trends should also significantly account for the functons in left and right VF presentations. In contrast to experiment I, which only demonstrated a marginal VF by SOA interaction, experiment II should show a significant interaction with an increase in the number of Ss. In addition, the three way interaction of mask by VF by SOA should be significant.

Differences accounting for the three way interaction should primarily be the result of the two masks affecting the VF differentially as a function of SOA. Although the type of processing characteristics for the separate VFs has not been defined for letter identification, it seems reasonable to assume that they are different (Cohen 1973 Levy-Agresti & Sperry 1968).

Experiment II

Method

Subjects. Twenty Ss participated in experiment II. The same requirements were used as in experiment I and the same credit was given. The only difference was that Ss who did not receive course credit were paid $4 instead of $2.

Stimuli

Target. The same stimuli were used.

Mask. One of the two masks used was the same as in experiment I and will be referred to as the 100% mask. The second mask was half as dense as the 100% mask and will be referred to as the 50% mask. The two masks are shown in figure 2. In all other respects the same parameters were used.

Procedure. There were two experimental conditions. One was a replication of experiment I and will be referred to as the 100% mask condition. The other condition was the same in all respects except that the 50% mask was used. Ten Ss participated in the 100% mask condition followed at least one day later by the 50% mask condition. The remaining ten Ss followed the reverse order.

Results

An analysis of variance for a repeated measures design was done. The independent variables were VF, SOA and mask. The dependent measure was again the number of letters correctly identified. The results indicated that order (i.e. whether Ss were exposed to the 50% or 100% mask first) was not significant nor did it contribute to any of the interactions except for the order by mask interaction. (See table 7.) The means for Ss receiving the 50% mask first followed by the 100% mask were 7.673 and 8.219 respectively. For the Ss receiving the 100% mask followed by the 50% mask the means were 7.462 and 7.904 respectively. The means suggest that there was a practice effect which interacted with the different masks. That is, there was a greater improvement among Ss who received the 50% mask first compared to Ss who were exposed to the 100% mask first. However, the means across both groups did not differ as indicated by the nonsignificance of the order effect.

Except for mask all remaining main effects were significant. Mean performance for mask was 7.840 and 7.788 for the 100% and 50% mask respectively. For VFs, mean performance were 7.531 for the LVF and 8.098 for the RVF. These results replicated experiment I as well as demonstrating RVF superiority for letter identification. The means for the different SOAs are listed in table 8 for the separate VFs as well as combined over VFs. These means are combined over mask conditions and therefore table 9 is included, reflecting the mean performance levels at each SOA for the two VFs in the two mask conditions.

There was a significant VF by SOA interaction which indicates that performance was differentially affected by

SOA for the two VFs. In addition, mask became a relevant variable in the three way interaction of mask by VF by SOA. So in addition to different performance characteristics for the two VFs as a function of SOA, the mask had a differential effect for the two VF as a function of SOA. In order to more clearly understand this three way interaction, each VF has been separately graphed as a function of SOA for the two mask condition, Figure 3 contains all four functions. Figures 4 and 5 represent the two mask conditions for the RVF and LVF respectively.

In the RVF (figure 5) for both masks maximum decrement occurs at 40 msec. Furthermore, the decrement from 30 to 40 msec and the improvement from 40 to 50 msec were significant for the two conditions as measured by the Duncan New Multiple Range Test. (See table 10 and 11.) The decrement in performance for the two mask conditions at 80 msec is not significant when compared against 70 msec but there is a significant improvement at 90 msec. Again for the two conditions improvement commences at the same time. The two functions therefore suggest that within the RVF the two masks did not differentially affect performance as SOA was varied. This was further assessed by testing for trends and then determining whether the trend components for each function were significantly different. The test for trends would give an indication as to the best equation(s) which would describe the function for the two mask conditions within the RVF. The test for trend differences for the two masks would also indicate whether the functions representing the two masks were the same.

The test for trends indicates a significant linear, quadratic and cubic trend for each mask condition in the RVF. (See table 12.) For the 100% mask condition approximately 47.9, 19.9 and 17.5% of the variance was accounted for by the linear, quadratic and cubic trend components respectively. Thus the variance accounted for by the three trends was approximately 85%. For the 50% mask condition, 28.7, 32.6 and 8.5% of the variance was accounted for by the linear, quadratic and cubic trends respectively. The total variance accounted for by the three trends was approximately 70%.

Since no a priori hypothesis was advanced concerning the affect of change in mask density on the components, the alpha level was adjusted for a posteriori commparisons (Kirk 1968, p 197). Only the linear trend was significantly different for the two mask conditions. A visual inspection of the graph for the two mask conditions within the RVF indicates that a linear change would result only after the interval of 50 msec since the two functions prior to this point are very similar. However, the specific point reflecting a change in the linear trend is not possible to determine.

Figure 6 has been included to demonstrate the replicability of the functions for experiment I and II for RVF presentation. Although different Ss participated in experiment II the degree of similarity of the functions are striking. In all three functions the decrement in performance begins between 20 and 30 msec with maximum decrement occuring at 40 msec. Rebound to masking occurs between 40 and 50 msec. Thus the period or width vulnerable to the mask for all three functions are the same. A comparison of the two experiments also demonstrates that the linear, quadratic and cubic trends are significant for the 100% masks. More important, however, is the fact that the variances accounting for the different trend components in experiment I and II was very similar. In experiment I they were 56.22, 19.60 and 11.73% for the linear, quadratic and cubic trends respectively as compared to 47.9, 10.9 and 17.5% (same order) for experiment II.

In conclusion, experiment I and II are very similar for the 100% mask condition within the RVF. In addition, the change in masks for experiment II does not significantly affect the two functions differentially until sometime after 50 msec.

In the LVF (see figure 6) for the 100% mask condition, maximum decrement in performance occurs between 20 and 40 msec SOA. The slight "improvement" at 30 msec is not significant as measured by the Duncan New Multiple Range Test (see table 13). The situation is quite different for the 50% mask condition. The maximum decrement in performance occurs at 20 msec. The decrement in performance at 20 msec is significantly different from the performance at both 10 and 30 msec as measured by the Duncan New Multiple Range Test. (See table 14.) Both the degree of decline and improvement is rapid for the 50% mask condition. So unlike the 100% mask condition the period vulnerable to the mask is very short.

Although a slight decrement in the LVF for the 100% mask condition is present at 70 and 110 msec these SOAs are not significantly different in performance when compared to the preceding SOAs (namely 60 and 100 msec respectively). The improvement from 70 to 80 msec is significant whereas the improvement from 110 to 120 msec is not. (See table 14.)

The graph of the two functions (figure 6) suggests that the masks have a greater differential impact on the first half of the function as compared to the latter half. Since the decrements in performance at 60 and 110 msec were not significant, it is not possible to determine whether a significant change or shift did not also occur in the latter portion of the functions for the two mask conditions. However, a test for significant trends will permit a comparison of the functions for the two mask conditions as well as determining the replicability of experiment I with experiment II.

The linear, quadratic and cubic trends were again significant for both mask conditions. The variance accounting for the linear, quadratic and cubic trends for the 100% mask condition were 57.8, 20.8 and 13.6% respectively. The total variance accounted for by these trends were 92%. For the 50% mask condition the variance accounting for the linear, quadratic and cubic trends were 77.3, 6.10 and 1.6% respectively which total 85%. Adjusting the alpha level for a posteriori comparisons it was determined that the cubic trend was significantly different for the two mask conditions. No other trends were significantly different (see table 15). The difference found in the cubic trend for the two mask conditions is most likely attributable to changes in the functions between 0 and 70 msec. This conclusion is based on the visual inspection of the two functions (figure 6) in which a cubic trend component is most apparent in the early portion of the curve.

Figure 7 was included so that the replicability of experiment II can be compared to experiment I. In the 100% mask condition the decrement and improvement in performance are quite similar for the two experiments. The decrement in performance persists until 30 msec for experiment I and 40 msec for experiment II. In both functions the initial rebound does not conclude until 60 msec. As mentioned before, the 50% mask condition generates a foreshortened duration of maximum vulnerability to the mask compared to the 100% mask condition for experiment I and II. The remaining half of the functions, from 70 to 120 msec, are similar. In both conditions in experiment II there is an apparent second point vulnerable to masking at 110 msec as in experiment I, but this point is not significant.

A comparison of the different trend components for experiment I and experiment II in the 100% mask condition reveals a distinct difference between the variance accounted for by the quadratic trend. They were 20.80 and 8.59% for experiment I and II respectively. The linear and cubic trends were quite similar. For experiment I they were 63.83 and 17.87% for the linear and cubic trends. For experiment II they were 57.8 and 13.6 (same order).

The difference in the quadratic trend component for experiment I and II may have inadvertantly been the result of the equipment. It is quite possible that the rise and decay time changed slightly for the t-scope bulbs as a function of age. If this was indeed the extraneous variable accounting for the difference between the two experiments for LVF presentation it would be interesting to determine why the effect did not significantly effect the RVF. However, this question is beyond the scope of this dissertation.

In conclusion, the 50% mask condition foreshortened the period of initial vulnerability leaving the remaining portion of the function unchanged.

To investigate the likelihood of parallel processing in the right hemisphere, Ss that showed at least a one letter decrement in performance at 110 msec SOA in the LVF for the 100% mask condition compared to both 100 and 120 msec SOA were separately assessed. Seven Ss were found to fit this criterion. When group means were graphed for these Ss it was found that three distinct decrements emerged in the LVF. (See figure 8.) Besides the decrement at 20 msec and the obvious one at 110 msec, a large decrement occurred at 70 msec. Post hoc comparisions revealed that the decrement at 70 msec was significant when compared to both 60 msec as well as 80 msec. ($p<.05$).

The vulnerability to the mask at three different SOAs suggest that three cognitive stages are responsible in letter identification within the LVF.

An analysis of variance for repeated measures, on the seven Ss showing the multiple decrements, revealed that neither the VF by SOA nor the mask by VF by SOA interaction were significant. This indicates that the mask did not significantly affect the two VFs differentially. The three way interaction reveals that the fields were not performing differently in the two mask conditions as a function of SOA. It is therefore not appropriate to analyze the data for trend differences to determine processing characteristics for the right and left VFs since they did not differ significantly as a function of mask across SOA. The results do suggest, however, that processing of letters is not performed by all Ss in a uniform way.

Discussion

Masking has a differential effect for left and right visual presentation as indicated by the significant field by SOA interaction. The assumption underlying central masking has been that some process or processes in the identification of the target is/are disrupted. Therefore the VF by SOA interaction suggests that differences between fields results from different processing characteristics being disrupted differentially. It was hoped that by utilizing different masks the disruption in the cognitive processes would affect the two VFs differentially as a function of SOA. The three way interaction, namely mask by VF by SOA was significant, supporting this prediction.

The functions generated by the 100% mask condition indicated that a U-shaped function did not adequately describe the function for either VF. Both functions required a linear, quadratic and cubic trend component. A truely U-shaped function would consist entirely of a quadratic trend component. The fact that three components were necessary indicates that processing for the left and right visual field encompassed more that one stage. However, it is unclear where these stages commence and terminate since the secondary components were not significant (at 70 and 110 msec) when all Ss were combined. Besides showing a significant three way interaction with a change in the mask, it should also be possible to identify the cognitive processing characteristics for the left and right hemispheres. It was found that the change in the mask yielded the same three trends as the initial mask did for both the left and right VFs. These results suggest that the strategy which the Ss utilized in the identification of the target did not change as a function of the density of the mask. If the trends which identfied the functions within a VF did change as a function of mask density then the processing characteristics or strategy in identifying letters may not have been constant. It was believed that if the two masks disrupted the processing of letters differentially it could be detected in either one of two ways. One way was by a shift in a portion of the function while the remaining portion remained constant and/or the variance that accounted for a particular trend would change as a function of the mask. The first method would indicate that a particular process was interfered with with respect to an increase or decrease in time. The latter method would only indicate that processing was disrupted.

In the LVF, changing the mask changed the initial portion of the curve (figure 5) leaving the remaining curve intact. This difference was supported by a significant change in the cubic trend component. The variance accounting for the cubic trend component decreased with the 50% compared to the 100% mask. The remaining trends did not change significantly as a function of the density of the mask. The results suggest that the stages necessary in identifying the T are multiple and that the same number of stages are required for the 50 and 100% mask.

The RVF also seems to require multiple processing for letter identification, as measured by the number of significant trend components. The linear trend was significantly different for the two conditions. The variance accounting for the linear trend decreased significantly with the 50% mask as compared to the 100% mask. Visual inspection of the functions (figure 4) indicates that the latter half of the function is primarily linear. The mask affected the later part of the function without affecting the first half, as indicated by the fact that no other trends are significantly different.

The nature of the VF by SOA interaction can now be outlined in more detail. Specifically maximum masking occurs sooner in the LVF compared to the RVF and an increase in vulnerability for LVF presentation occurs compared to RVF presentation as measured by a wider "U". These results are consistent with Experiment I. The mask by VF by SOA interaction permits a more detailed analysis concerning these differences. The mask affects the earlier cognitive operations in the LVF as measured by a significant change in the cubic trend. In contrast to the LVF, the mask affects only the later portion of the function for RVF presentation. The processing characteristics for the two VFs are therefore distinctly different. If they were not the mask should have affected them in a similar manner.

In summary, masking has a more pronounced deleterious affect on the LVF than the RVF, initial performance decrements can be detected sooner in the LVF than the RVF, and unlike previous reports involving foveal masking which had demonstrated a single U-shaped function, these findings reveal a multiple component function. In addition, the period of initial vulnerability in the LVF is foreshortened with the 50% mask. In contrast to the LVF, the change in the mask affects the later portion of the function in the RVF. Finally, more than one stage is necessary in the identification of letters.

General Discussion

In this section, an attempt will be made to integrate the results from Experiment I and II with previous research in laterality and processing differences found between the two hemispheres. Specifically, an explanation to account for cognitive processing occuring in the right hemisphere (RH) before the left hemisphere (LH) will be discussed with respect to iconic memory. Processing characteristics will also be identified and discussed in relationship to density changes in the mask affecting only RH performance. In addition, an attempt will be made to account for the fact that only the first half of the function is dramatically different for the two VFs. Finally, a discussion of future research in which masking is used to increase the understanding of laterality will be assessed.

Cognitive Processing. In both experiment I and II maximum decrement in performance occurs in the LVF first. A possible explanation of this affect is that the cognitive operation necessary in the identification of the target letters commences earlier in the RH as compared to the LH and thus becomes vulnerable to the mask at an earlier time. This would be possible if incoming information were in a form which would be more compatible with processing strategies in the RH. Evidence that this might in fact be the case comes from Sperling's (1960) classical work. He demonsrtated that a crude form of analysis occurring early in time results in a global representation of the stimulus. It is described as a global representation since Ss cannot report the item but can tell you the number of items making up the array. Ss were presented with an array of nine letters, three rows of three letters each. Generally five letters could be reported. However, using a partial report procedure he found that more letters were available than could usually be reported. By matching three different tones to the three rows of letters, Ss were found to be able to report the row of letters which matched the tone designating a particular row. This was possible despite the fact that the tone designating the particular row was initiated only after the stimulus had terminated. As the interval between the letter array and tone was increased the number of letters that could be reported decreased to five. (Estimates of letters that could be reported using partial reports were derived by multiplying the number of letters reported correctly by the number of letters in the array.) This indicates that although all letters were available upon termination of the stimulus the persistent image decays quickly.

Phemenologically the S believes that the letters are actually still being presented longer than their actual duration. Neisser (1967) has called this persisting image the icon. The fact that all letters are available at the same time suggests that processing is parallel in nature. In addition, the representation of the stimulus in iconic form is most likely visuospatial since processing of the stimulus for iconic memory has been identified at the retina (Sakitt 1975). This would suggest that higher cortical areas are not responsible for the existence of the persistant image, and eliminates the possiblity of any type of analytic process.

Sakitt (1975) was able to demonstrate the locus of process as occurring at the retina using a monochromatic subject who has only functional rods and therefore is colorblind. He presented white letters tachistoscopically on a white background and found that the S was unable to detect the letters regardless of the birghtness of the stimulus. This was due to the saturation of the rods. However, when the S closed her eyes the letters became visible. Since saturation has been identified at the rods, the formation of the icon must occur at and not after the rods. This implies that the formation of the icon is a peripheral event.

Further support that an early form of processing is visualspatial comes from a group of studies by Posner. Posner & Mitchell (1967) demonstrated that when Ss are asked to match two stimuli such as letters, a physical match is faster than a name match. That is, if the letters are the same physically (AA) then RT will be faster than if only the name identifies them as being alike (Aa). What is intriguing is that the difference in the RT decreases to zero if the interval between the first and second letter is increased (Posner & Keel 1967; and Posner, Poies, Eichelman & Taylor 1969). This suggests that the strategy has changed as the interval increases. It is very likely that the physical match can be accomplished by comparing the visuospatial configuration which is formed iconically if the interval between the letters is small, but as the interval increases the icon decays, making this strategy impossible. Now the letters have to be encoded in a similar way as the name match in order to be able to identify the two letters as the same or different.

Posner, et al. (1969), found that if a mask is presented between the first and second letter the difference between the physical and name match is unaffected. This would seem to minimize the role the icon plays in matching the two stimuli when the interval is short since the icon is known to be affected by a mask (Sperling 1964). However, the RT for both the name and physical match inreases significantly for the mask condition. It is therefore unlikely that the same strategy is employed with and without the mask.

In summary, information at the retina seems to be processed in parallel and as a holistic visuospatial representation of the stimulus. This form, known as the icon, is probably maintained up to the visual cortex as indicated by Carlson (1977), "... the visual system maintains the spatial code seen on the retinal mosaic all the way up to visual cortex. There is a retinotopic representation on the cortex" (p 204). Therefore the hemisphere which can most easily handle the incoming information in iconic form would in all likelihood initiate processing first. The most likely candidate is the RH.

Levy-Agresti & Sperry (1968) have described the nature of processing in the RH as gestalt-like and the LH as analytic. These processing differences associated with the left and right hemispheres are based on commissurotomized patients. These and similar terms have been used to identify the hemispheres in normals as discussed below. But first it may be helpful to clarify gestalt and analytic processing. Gestalt processing has been associated with terms like parallel processing, holistic and visuospatial. Inherent in all these terms is finding an insignificant increase in RT as the number of elements in an array increases for experimental tasks. Analytic processing on the other hand is associated with serial processing which generally would be reflected by increases in RT as the elements in an array increases (Sternberg 1975). So, for example, if RT increased as the number of letters in the array increased and the increase was found to be a constant for each additional letter, then the processing would be characterized as serial. However, if RT was not appreciably affected by increases in the number of letters in the array that the S had to respond to, then processing would be considered parallel.

An example demonstrating processing strategies in the left and right hemisphere is Cohen's work (1975), in which increasing the number of letters in an array did not significantly increase RT for LVF presentation, but did for RVF presentation. The Ss task was to determine whether all the letters were the same or different. According to Cohen "the LH is processing the set serially while the RH processes holistically or in parallel" (p 351) for this particular task.

Patterson and Bradshaw (1973) found similar results using faces instead of letters as stimuli. Faces that differed in only 1 element compared to a memorized schematic face, required longer RT in the RH. But when 3 features were different or a global change occurred, the LH required a longer RT. This would indicate that the processing technique utilized by the RH is gestalt or holistic, and thus would account for the difficulty the RH has when only one element of the face was changed.

Similarly, Umilta, Bagnara & Simion (1978) found that hemispheric superiority can be a function of the complexity of the task. For simple geometric forms RT was faster for the LH to a same/different task. However for the more complex geometric forms RT was faster for the RH. The constraints of the task makes it unlikely that the complex figures were verbally encoded and thus the results would suggest that the RH processed the information visuospatially.

In summary, the decrement in performance that occurs first in the RH is best explained by the RH initiating a cognitive operation before the LH. This is possible because the incoming information is already in a form which the RH can utilize. An alternate hypothesis is that the decrement that occurs first in the RH is a reflection of the hemisphere's inferior performance in this task. The worse a hemishere is at a particular task the greater is its vulnerability to the mask and hence the sooner its performance will bottom out. Although this assumption sounds reasonable, recent data does not support this. Cohen (1980) in experiment 2 found that when faces were masked, the RH still showed the decrement sooner than the LH. This was despite the fact that the RH was superior in this task.

Masking effect on the RH. Another major finding was the dramatic change in the "U" as a function of the density of the mask in LVF presentation. As the density changed from 100 to 50%, the width of the "U" becomes much narrower or foreshortened. In contast to the LVF the RVF was unaffected by the density change in the first half of the performance function. These findings again are consistent with characterizing the processing in the RH as visuospatial. As the T letters become embedded in a mask with greater density, more time is required to determine the configuration if processing is visuospatial. These findings are supportive of Levine's (1978) finding in which a right brain damaged patient had little difficulty in identifying objects which were used by the examiner "e.g. screwing motion with screwdriver" (p. 355) but could not identify objects when surrounded by unrelated objects. Thus, embedding an object in unrelated objects or noise requires RH functioning.

Further support comes from Hellige & Webster (1979). Their experiment was similar to experiment I except that both forward and backward masking was evaluated when the luminance of the T and M were equal. They found that overall letter identification was superior in the LVF compared to the RVF. Further analysis indicated that earlier SOAs (up to and including 30 msec) were the major contributors to the effect. The authors interpret these results as indicating the superiority of the RH in extracting relevant features when a T is embedded in a mask.

In experiment II, the nonsignificant change as a function of mask density for the RVF indicates that processing is different in the LH as compared to the RH. Although the decrement in performance which represents a cognitive operation cannot be identified as analytic, the above results do indicate that it is not visuospatial.

Another important result was that the second half of the function did not show as dramatic a difference as the first half of the function when the two VFs were compared. The major difference in the functions occurred up to approximately 60 msec. This was especially true in experiment II for both the 50 and 100% mask conditions across VFs. A viable explanation is that information which was presented to the RH was transferred to the LH. Therefore the similarity that is noted in the latter part of the performance function reflects the performance in the LH only. This explanation would be in accordance with Moscovitch & Catlin's (1970) research among others. They believe that interhemispheric transfer (ITT) of information occurs when stimuli are received by the hemisphere not generally identified as the "dominant one" for that particular task. Moscovitch & Catlin, for example, determined that the ITT was on the order of 10 msec. In their study letters were lateralized 4.2 degrees and required a verbal response. Filbey & Gazzaniga found RT differences to be approximately 30 msec for the detection of a dot. Again the response was verbal but the stimulus was only lateralized 1 degree.

McKeever & Huling (1971) discusses the descrepancy of the ITT caluculated by Filbey & Gazzaniga compared to previous researchers. McKeever & Gill (1972) found that the descrepancy in time could be accounted for by the degree the stimuli were lateralized from fixation. The greater the stimuli is lateralized from fixation the less the ITT. In still another paper, McKeever, Gill and Van Deventer (1975) found that they could not replicate the differences found by Filbey and Gazzaniga. However when using letters which were lateralized 1.6 degrees they found that right-handers performed 39 msec faster for RVF presentation. The difference in ITT found by Mc Keever et al (1975) compared to Moscovitch & Catlin (1970) may be the result of requiring Ss to report a digit at fixation in the latter experiment in addition to reporting the letter.

An assumption which is generally made in studies which measure ITT is that information is transferred at the same rate regardless whether digits, letters or dots are used. From experiment II this assumption may not be entirely correct. If in fact information to the RH is transferred to the contralateral hemisphere then the period of vulnerability in the masking experiment seems to be a good indicator for the time required to process incoming information before the transfer can occur. It is unlikely that the incoming information can be transferred in the form in which it arrives. Instead some transformation occurs before going across the corpus callosum. Although different stimuli were not used in the present research, different density masks were, and as previously discussed density had a dramatic affect in increasing the initial cognitive operation in the RH. The duration of this stage must be determined before any accurate measure of ITT can occur.

In summary then, the input to the nondominant hemisphere for a particular stimuli must be processed before interhemispheric transfer can occur. The processing time may be contingent on the type of stimuli. It has been demonstrated (in Experiment II) that the density of a mask can influence processing time and therefore it is not unlikely that different stimuli would also require varying amounts of processing time.

Future Research. Both Experiments I and II have contributed to a better understanding of processing in the right and left hemispheres. The stimuli however have been constant both in number and type for both experiments. It is suggested that varying the number of letters in the array from 1 to 4 (or 5) would support some of the interpretations advanced in the previous discussion. If a visuospatial and parallel form of processing characterizes the RH then increases in the letter array should have little effect in the performance function. The stability of the function should compare to the LH function as mask density is changed.

A dramatic change should occur for LH function as the number of letters in the array increase, since a serial form of processing has been suggested by many researchers. In all likelihood the change would be an increase in the vulnerability indicated by a wider width in the "U."

Another change would be using stimuli which are known to be RH related such as faces. The strategy of the task would obviously be quite different than for letter identification, and therefore the performance function should represent this difference. More interesting however would be finding a similarity in the latter portion of the function for the left and right hemispheres. This would further support transference of processing to the more appropriate hemisphere for a given task, in this case the RH. Since the RH processes information differently as compared to the LH, the latter portion of the function should be different from the functions (for the later SOAs) representing letter identification.

For all of the future experiments discussed thus far a different approach in testing Ss is suggested. Instead of keeping the luminance ratio constant for the T and M, it may be advantageous to manipulate this parameter. Although a repeated measures design is a powerful paradigm when compared to a randomized design, some small but interesting changes may have been washed out due to the variability across Ss. This includes nonsignificant decrements for the latter part of the functions.

It is possible that decreasing the luminance ratio for the T and M may increase the number of Ss demonstrating multiple decrements. Once this is accomplished, a critical analysis of changes in the function would be possible. That is, it would then be possible to evaluate the multiple decrements as a function of increases in the number of letters making up the target as well as comparing the number of decrements for different stimuli (letters vs. faces) and VFs.

Dichoptic masking has been demonstrated by Turvey (1973) using a pattern mask. However, little work has been done to demonstrate masking across VFs. Although central masking occurs post-retinally, it is unclear where the disruption occurs. If masking is possible when the T and M are presented to different VFs then the locus of masking would probably be at a higher cortical structure. This could be verfied further by using a clinical population. Specifically, splenium patients (patients with the posterior corpus callosum cut) should be unaffected by the M when the M is presented to the opposite VF. This would result because the posterior portion of the corpus callosum transfers visual information from the occipital areas. Therefore, damage to this area would decrease the likelihood of the mask transferring to the opposite hemishere and disrupting the ongoing cognitive process necessary to the identification of the stimuli.

Finally if a stable function can be attained across normal Ss by titrating the luminance ratio of the T and M, then clinical groups can be evaluated against a generalized normal function. Although certain tracts may be determined to be structurally sound (based on the CAT scan for an example) it is entirely possible that functional deficits exist. Concomitant with using masking as a clinical tool for diagnosis is the possibility of utilizing visual evoked potentials (VEPs). In brief, VEPs are the averaging of EEG over a specific time range. The averaging generally commences with a click (for auditory EPs) or a flash (for visual EPs). Noise in the system is assumed to be random and therefore would drop out when hundreds of sweeps are averaged. Although further research is necessary for coordinating the two techniques, these methods of assessing a clinical group might be quite powerful. Masking could indicate the cognitive deficits, which then could be verfied and possibly localized by EPs.

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Table 1

Analysis of Variance for Experiment I

Source	Sum of Squares	df	Mean Square	F-Test	Significance
Visual Field (VF)	39.287	1	39.287	18.094	0.002
residual	21.713	10	2.171		
SOA	495.713	12	41.268	18.813	0.001
residual	263.235	120	2.194		
VF x SOA	39.986	12	3.332	1.738	0.067
residual	230.009	120	1.917		

Table 2

Experiment I

Percent change in performance as a function of SOA

SOA	RVF	LVF	Combined VF
0	4.2%	5.4%	2.0%
10	3.1%	4.3%	3.8%
20	4.5%	15.1%	9.0%
30	13.0%	16.3%	18.1%
40	22.9%	7.5%	13.9%
50	3.6%	4.3%	3.4%
60	6.6%	4.7%	2.9%
70	2.5%	3.5%	3.4%
80	3.0%	5.5%	3.5%
90	6.4%	6.5%	7.3%
100	9.9%	9.8%	11.3%
110	11.6%	6.6%	9.3%
120	8.6%	10.4%	12.0%

Table 3

Experiment I

Mean performance as a function of SOA

SOA	R VF	L VF	Combined VF
0	7.273	6.727	7.000
10	7.000	5.909	6.455
20	7.000	4 545	5.773
30	5.727	4.182	4.955
40	5.000	5.273	5.136
50	6.909	6.182	6.545
60	6.818	6.545	6.682
70	7.545	6.545	7.045
80	7.818	8.091	7.955
90	8.455	8.091	8.273
100	9.182	8.727	8.955
110	9.364	7.818	8.591
120	9.091	8.909	9.100

Table 4

Duncan's New Multiple Range Test

for RVF presentation

	SOA	40	30	60	50	10	20	0	70	80	90	110	100	120
SOA	X	5.00	5.72	6.82	6.91	7.00	7.00	7.27	7.55	7.82	8.45	9.09	9.18	9.36
40	5.00		0.72	1.82*	1.91*	2.00*	2.00*	2.27*	2.55*	2.82*	3.45*	4.09*	4.18*	4.36*
30	5.72			1.10	1.19	1.28	1.28	1.55*	1.83*	2.10*	2.73*	3.37*	3.46*	3.64*
60	6.82				0.09	0.18	0.18	0.45	0.73	1.00	1.63*	2.27*	2.36*	2.54*
50	6.91					0.09	0.09	0.36	0.64	0.91	1.54*	2.18*	2.27*	2.45*
10	7.00						0.00	0.27	0.55	0.82	1.45*	2.09	2.18*	2.36*
20	7.00							0.27	0.55	0.82	1.45*	2.09*	2.18*	2.36*
0	7.27								0.28	0.55	1.18	1.82*	1.91*	2.09*
70	7.55									0.27	0.90	1.54*	1.63*	1.81*
80	7.82										0.63	1.27*	1.36*	1.54*
90	8.45											0.64	0.73	0.91
110	9.09												0.09	0.27
100	9.18													0.18

*$p < .05$

Table 5

Duncan's New Multiple Range Test

for LVF presentation

	SOA	30	20	40	10	50	60	70	0	110	80	90	100	120
SOA	X	4.18	4.55	5.72	5.91	6.18	6.55	6.55	6.73	7.82	8.09	8.09	8.73	8.91
30	4.18		0.37	1.54	1.73*	2.00*	2.37*	2.37*	2.55*	3 64*	3.91*	3.91*	4.55*	4.73*
20	4.55			1.17	1.36*	1.63*	2.00*	2.00*	2.18*	3.27*	3.54*	3.54*	4.18*	4.36*
40	5.72				0.19	0.46	0.83	0.83	1.01	2.10*	2.37*	2.37*	3.01*	3.19*
10	5.91					0 27	0.64	0.64	0.82	1.91*	2.18*	2.18*	2.82*	3.00*
50	6.18						0.37	0.37	0.55	1.64*	1.91*	1.91*	2.55*	2.73*
60	6.55							0.00	0.18	1.27	1.54*	1.54*	2.18*	2.36*
70	6.55								0 18	1.27	1.54*	1.54*	2.18*	2.36*
0	6.73									1 09	1.36	1.36	2.00*	2.18*
110	7.82										0.27	0.27	0.91	1.09
80	8.09											0.00	0.64	0.82
90	8.09												0.64	0.82
100	8.73													0.18

*p< .05

Table 6

Experiment I

Test for trends

Source	Sum of Squares	df	Mean Squares	F
RVF				
linear trend	127.385	1	127.385	66.45**
quadratic trend	44.416	1	44.416	23.17**
cubic trend	26.586	1	26.586	13.87**
LVF				
linear trend	196.996	1	196.996	102.76**
quadratic trend	26.505	1	26.505	13.83**
cubic trend	55.137	1	55.137	28.76**
Residual	230.009	120	1.917	

**p<.01

Table 7

Analysis of Variance for Experiment II

Source	Sum of Squares	df	Mean Square	F-Test
Order (Ord)	18.047	1	18.047	0.552
residual	588.694	18	32.705	
Mask	0.701	1	0.701	0.134
Ord x Mask	63.507	1	63.507	12.101**
residual	94.464	18	5.248	
Visual Field (VF)	83.677	1	83.677	38.482***
Ord by VF	8.316	1	8.316	3.824
residual	39.140	18	2.174	
SOA	933.740	12	77.812	24.700***
Ord x SOA	33.015	12	2.751	0.873
residual	680.466	216	3.150	
M x VF	2.701	1	2.701	2.031
Ord x M x VF	0.809	1	0.809	0.608
residual	23.933	18	1.330	
M x SOA	24.061	12	2.005	1.539
Ord x M x SOA	23.554	12	1.963	1.506
residual	281.445	216	1.303	
VF by SOA	120.584	12	10.049	6.099***
Ord x VF x SOA	24.146	12	2.012	1.221
residual	355.878	216	1.648	
M x VF x SOA	31.961	12	2.663	2.197*
M x VF x SOA x Ord	12.454	12	1.038	0.856
residual	261.885	216	1.212	

***$p < .001$
**$p < .01$
*$p < .05$

Table 8

Experiment II

Mean performance as a function of SOA for the combined masked conditions

SOA	R VF	L VF	Combined VF
0	8.450	7.275	7.862
10	7.725	6.850	7.287
20	7.650	5.600	6.625
30	7.175	6.650	6.912
40	6.050	6.500	6.275
50	7.700	6.975	7.337
60	7.850	7.325	7.587
70	8.225	6.900	7.562
80	7.650	8.125	7.887
90	8.925	8.500	8.712
100	9.375	9.075	9.225
110	9.275	8.725	9.000
120	9.225	9.400	9.312

Table 9

Experiment II

Mean performance for each VF for the two mask conditions as a function of SOA

	LVF		RVF	
SOA	100%	50%	100%	50%
0	7.900	6.650	8.300	8.600
10	7.050	6.650	7.550	7.900
20	6.000	5.200	7.450	7.850
30	6.550	6.750	7.000	7.350
40	6.150	6.850	5.800	6.300
50	6.800	7.150	7.550	7.850
60	7.600	7.050	7.600	8.100
70	7.050	6.750	8.400	8.050
80	7.950	8.300	8.000	7.300
90	8.700	8.300	9.200	8.650
100	9.100	9.050	9.350	9.400
110	8.750	8.700	9.500	9.050
120	9.300	9.500	9.250	9.200

Table 10

Duncan's New Multiple Range Test

for 100% RVF presentation

	SOA	40	30	20	10	50	60	80	0	70	90	120	100	110
SOA	X	5.80	7.00	7.45	7.55	7.55	7.60	8.00	8.30	8.40	9.20	9.25	9.35	9.50
40	5.80		1.20*	1.65*	1.75*	1.75*	1.80*	2.20*	2.50*	2.60*	3.40*	3.45*	3.55*	3.70*
30	7.00			0.45	0.55	0.55	0.60	1.00*	1.30*	1.40*	2.20*	2.25*	2.35*	2.50*
20	7.45				0.10	0.10	0.15	0.55	0.85	0.95*	1.75*	1.80*	1.90*	2.05*
10	7.55					0.00	0.05	0.45	0.75	0.85	1.65*	1.70*	1.80*	1.95*
50	7.55						0.05	0.45	0.75	0.85	1.65*	1.70*	1.80*	1.95*
60	7.60							0.40	0.70	0.80	1.60*	1.65*	1.75*	1.90*
80	8.00								0.30	0.40	1.20*	1.25*	1.35*	1.50*
0	8.30									0.10	0.90*	0.95*	1.05*	1.20*
70	8.40										0.85	0.85	0.95*	1.10*
90	9.20											0.05	0.15	0.30
120	9.25												0.10	0.25
100	9.50													0.15

*p<.05

Table 11

Duncan's New Multiple Range Test

for 50% RVF presentation

	SOA	40	80	30	20	50	10	70	60	0	90	110	120	100
SOA	X	6.30	7.30	7.35	7.85	7.85	7.90	8.05	8.10	8.60	8.65	9.05	9.20	9.40
40	6.30		1.00*	1.05*	1.55*	1.55*	1.60*	1.75*	1.80*	2.30*	2.35*	2.75*	2.95*	3.10*
80	7.30			0.05	0.55	0.55	0.60	0.75	0.80	1.30*	1.35*	1.75*	1.95*	2.10*
30	7.35				0.50	0.50	0.55	0.70	0.75	1.25*	1.30*	1.70*	1.90*	2.05*
20	7.85					0.00	0.05	0.20	0.25	0.75	0.80	1.20*	1.35*	1.55*
50	7.85						0.05	0.20	0.25	0.75	0.80	1.20*	1.35*	1.55*
10	7.90							0.15	0.20	0.70	0.75	1.15*	1.30*	1.50*
70	8.05								0.05	0.55	0.60	1.00*	1.15*	1.35*
60	8.10									0.50	0.55	0.95*	1.10*	1.30*
0	8.60										0.05	0.45	0.60	0.80
90	8.65											0.40	0.55	0.75
110	9.05												0.15	0.35
120	9.20													0.20

$^*p < .05$

Table 12

Experiment II

Test for trends

RVF presentation

Source	Sum of Squares	df	Mean Squares	F
100%				
linear trend	133.847	1	133.847	110.44**
quadratic trend	55.447	1	55.447	45.75**
cubic trend	48.770	1	48.770	40.25**
50%				
linear trend	51.508	1	51.508	42.50**
quadratic trend	58.338	1	58.338	48.17**
cubic trend	15.273	1	15.273	12.60**
Differences in masks				
diff in lin trend	9.65	1	9.65	7.96*
diff in quad trend	0.02	1	0.02	0.02
diff in cub trend	4.73	1	4.73	3.90
residual	261.885	216	1.212	

**p<.01

*p<.05/3 (alpha level adjusted for posteriori comparisons)

Table 13

Duncan's New Multiple Range Test

for 100% LVF presentation

	SOA	20	40	30	50	10	70	60	0	80	90	110	100	120
SOA	X	6.00	6.15	6.55	6.80	7.05	7.05	7.60	7.90	7.95	8.70	8.75	9.10	9.30
20	6.00		0.15	0.55	0.80	1.05*	1.05*	1.60*	1.90*	1.95*	2.70*	2.75*	3.10	9.30*
40	6.15			0.40	0.65	0.90	0.90*	1.45*	1.75*	1.80*	2 55*	2.60*	2.95*	3.15*
30	6.55				0.25	0.50	0 50	1.05*	1.35*	1. *	2.15*	2.20*	2.55*	2.75*
50	6.80					0 25	0.25	0.80	1.10*	1.15*	1.90*	1.95*	2.30*	2.50*
10	7.05						0.00	0.50	0.85	0 90	1.65*	1.70*	2.05*	2.25*
70	7.05							0.50	0.85	0.90	1.65*	1.70*	2.05*	2.25*
60	7.60								0.30	0.35	1.10*	1.15*	1.50*	1.70*
0	7.90									0.05	0.80	0.85	1.20*	1.40*
80	7.95										0.75	0.80	1.15*	1.35*
90	8.70											0.05	0.40	0.60
110	8.75												0.35	0.55
100	9.10													0.20

*p<.05

Table 14

Duncan's New Multiple Range Test

for 50% LVF presentation

	SOA	20	0	10	30	70	40	60	50	80	90	110	100	120
SOA	X	5.20	6.65	6.55	6.75	6.75	6.85	7.05	7.15	8.30	8.30	8.70	9.05	9.50
20	5.20		1.45*	1.45*	1.55*	1.55*	1.65*	1.85*	1.95*	3.10*	3.10*	3.50*	3.85*	4.30*
0	6.65			0.00	0.10	0.10	0.20	0.40	0.50	1.65*	1.65*	2.05*	2.40*	2.85*
10	6.65				0.10	0.10	0.20	0.40	0.50	1.65*	1.65*	2.05*	2.40*	2.85*
30	6.75					0.00	0.10	0.30	0.40	1.55*	1.55*	1.95*	2.30*	2.75*
70	6.75						0.10	0.30	0.40	1.55*	1.55*	1.95*	2.30*	2.75*
40	6.85							0.20	0.30	1.45*	1.45*	1.85*	2.20*	2.65*
60	7.05								0.10	1.25*	1.25*	1.65*	2.00*	2.45*
50	7.15									1.15*	1.15*	1.55*	1.90*	2.35*
80	8.30										0.00	0.40	0.75	1.20*
90	8.30											0.40	0.75	1.20*
110	8.70												0.35	0.80
100	9.05													0.45

*$p < .05$

Table 15

Experiment II

Test for trends

LVF presentation

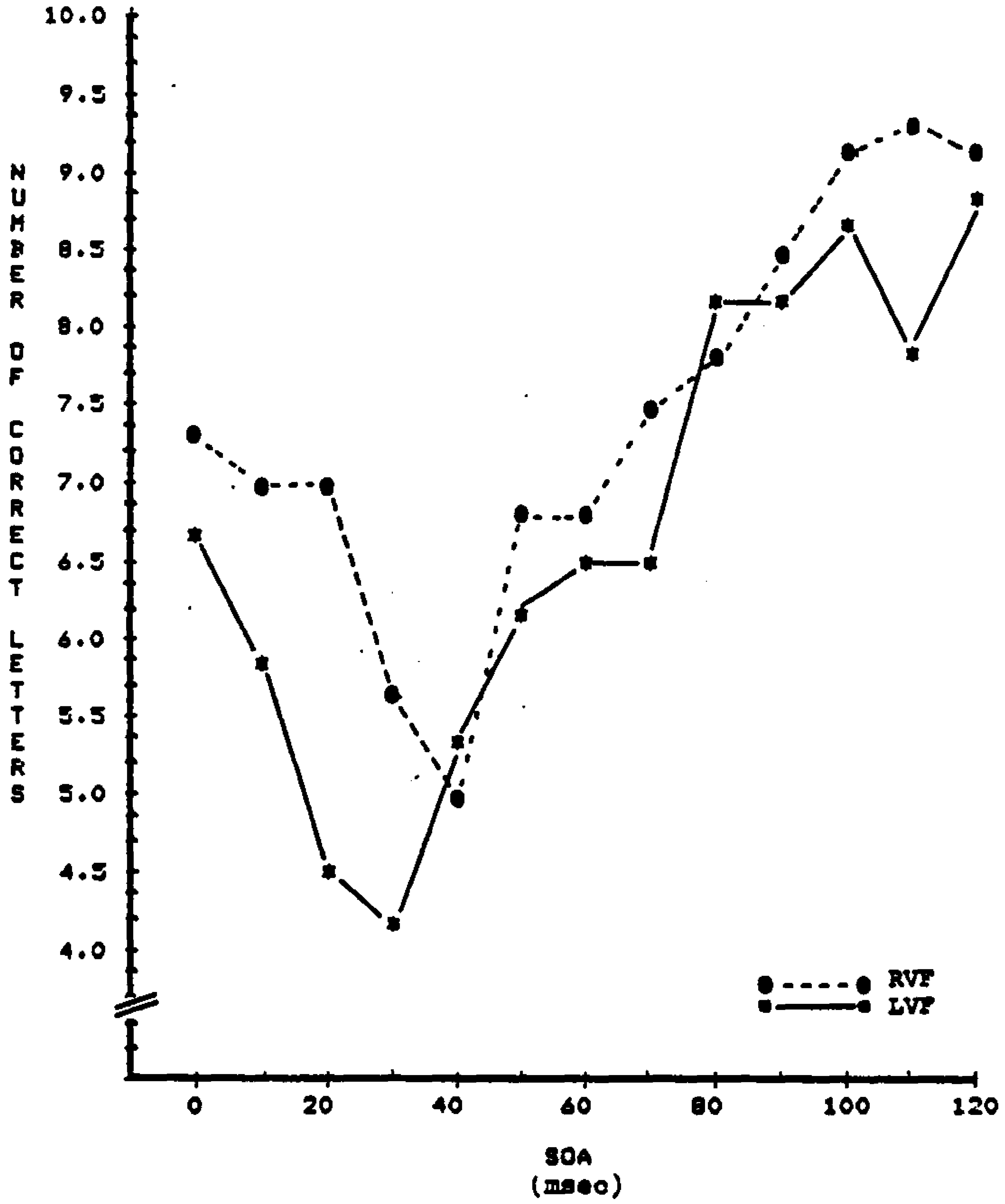
Source	Sum of Squares	df	Mean Squares	F
100%				
linear trend	172 325	1	172.875	142.18**
quadratic trend	61.875	1	61.875	51.05**
cubic trend	40.420	1	40.420	33.35**
50% mask				
linear trend	273.627	1	273.627	225.77**
quadratic trend	21.601	1	21.601	17.82**
cubic trend	5.640	1	5.640	4.65**
Differences in masks				
diff in lin trend	5.83	1	5.83	4.81
diff in quad trend	5.18	1	5.18	4.27
diff in cub trend	10.62	1	10.62	8.76*
Residual	261.885	216	1.212	

**p<.01

*p<.05/3 (alpha level adjusted for posteriori compairsons)

Figure Captions

Figure 1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9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
NUMBER OF CORRECT LETTERS
0
20
40
60
80
100
120
SOA
(msec)
RVF
LVF

Figure 2

100%
MASK

50%
MASK

Figure 3

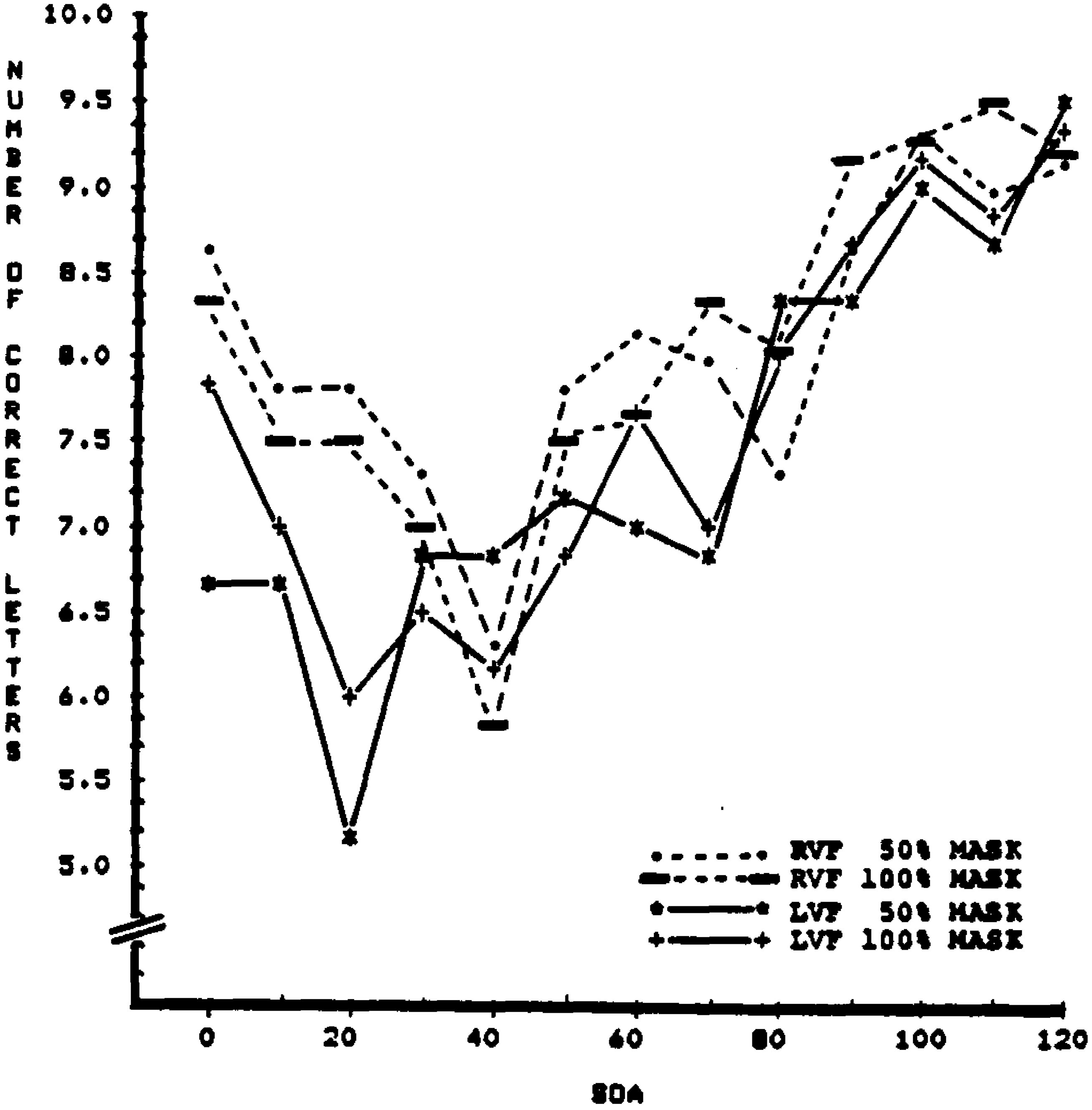

NUMBER OF CORRECT LETTERS
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
0
20
40
60
80
100
120
SOA
RVF 50% MASK
RVF 100% MASK
LVF 50% MASK
LVF 100% MASK

Figure 4

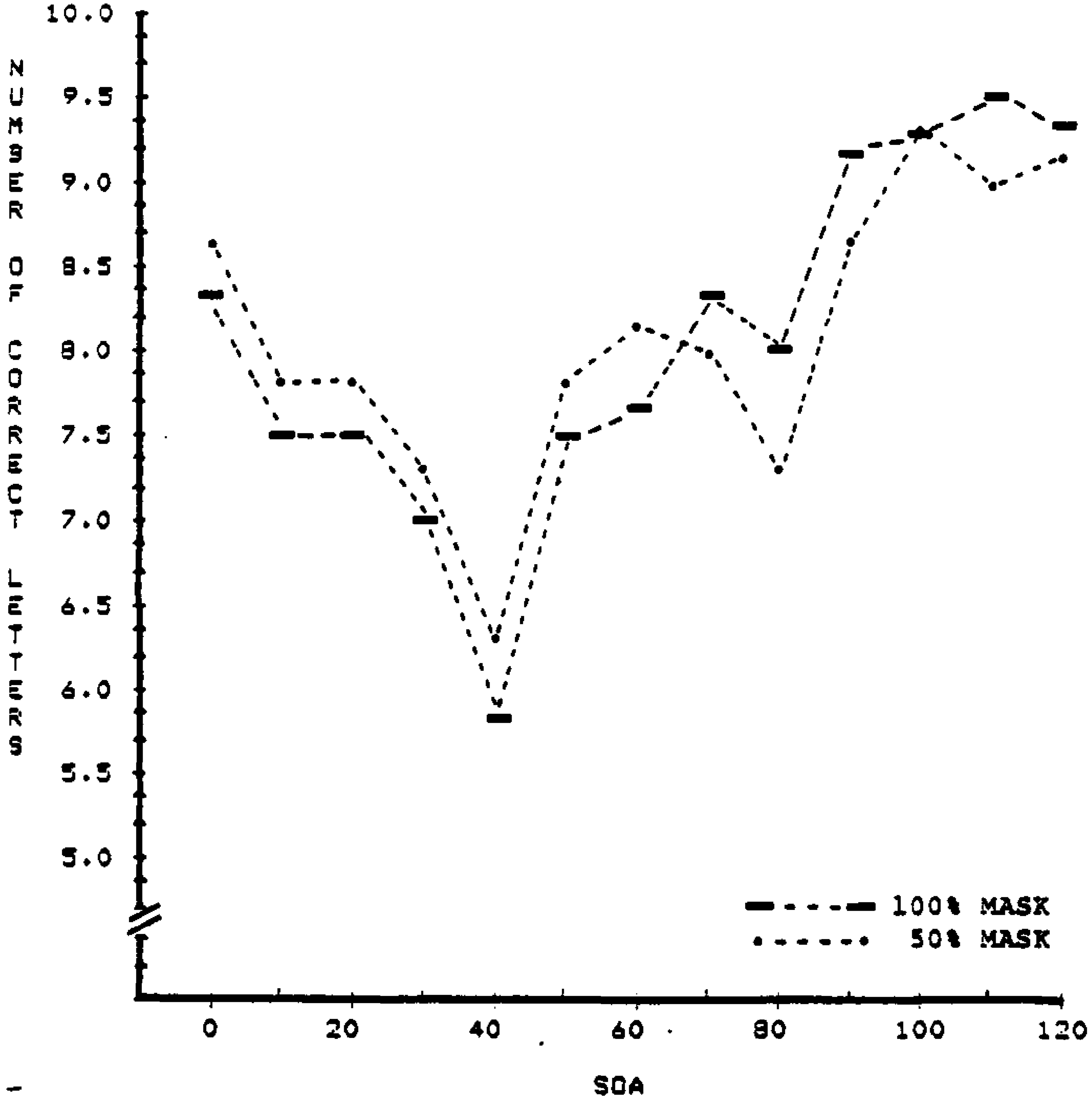

10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
NUMBER OF CORRECT LETTERS
0
20
40
60
80
100
120
SOA
100% MASK
50% MASK

Figure 5

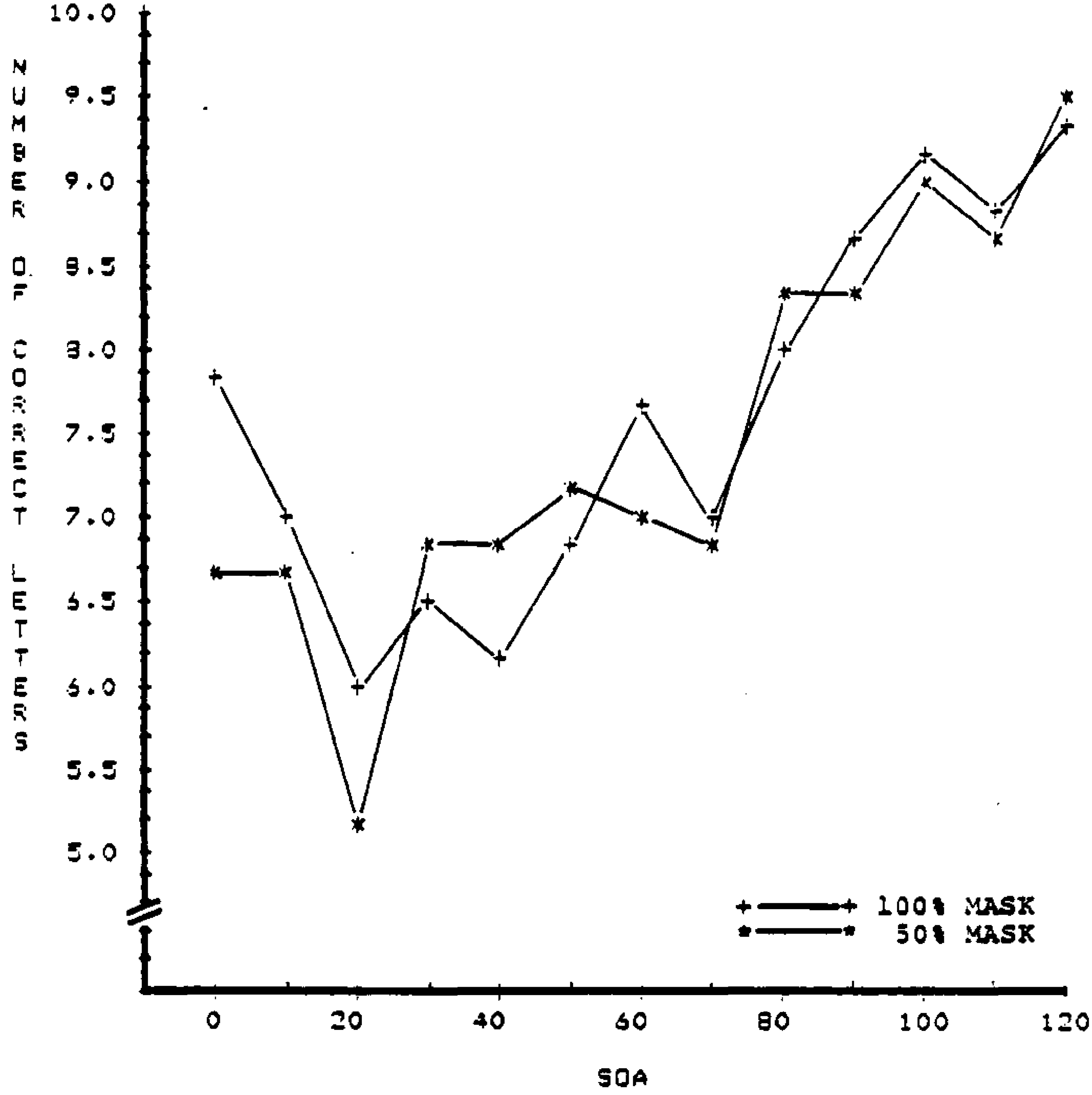

10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
NUMBER OF CORRECT LETTERS
0
20
40
60
80
100
120
SOA
100% MASK
50% MASK

Figure 6

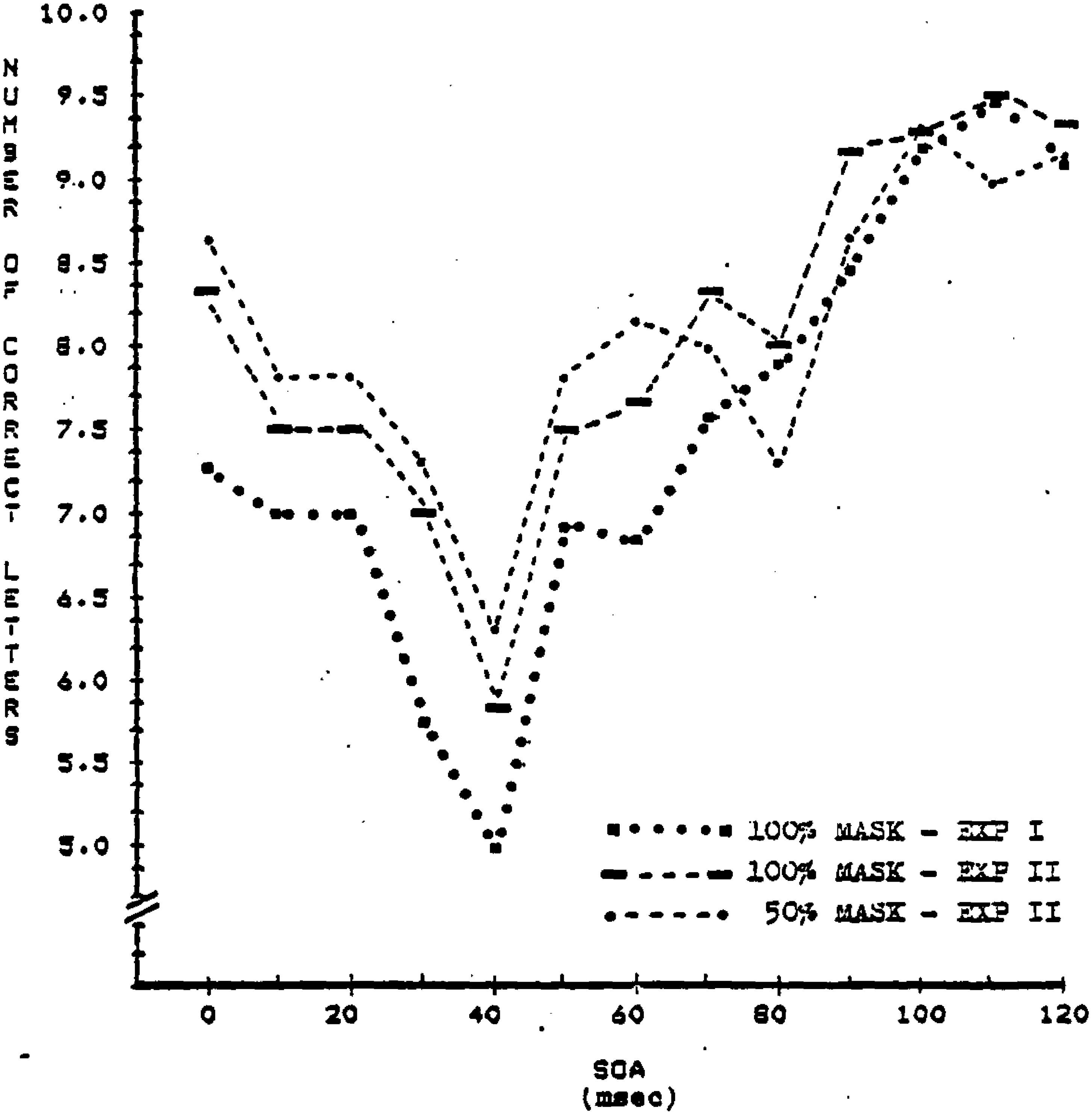

NUMBER OF CORRECT LETTERS
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
0
20
40
60
80
100
120
SOA
(msec)
100% MASK - EXP I
100% MASK - EXP II
50% MASK - EXP II

Figure 7

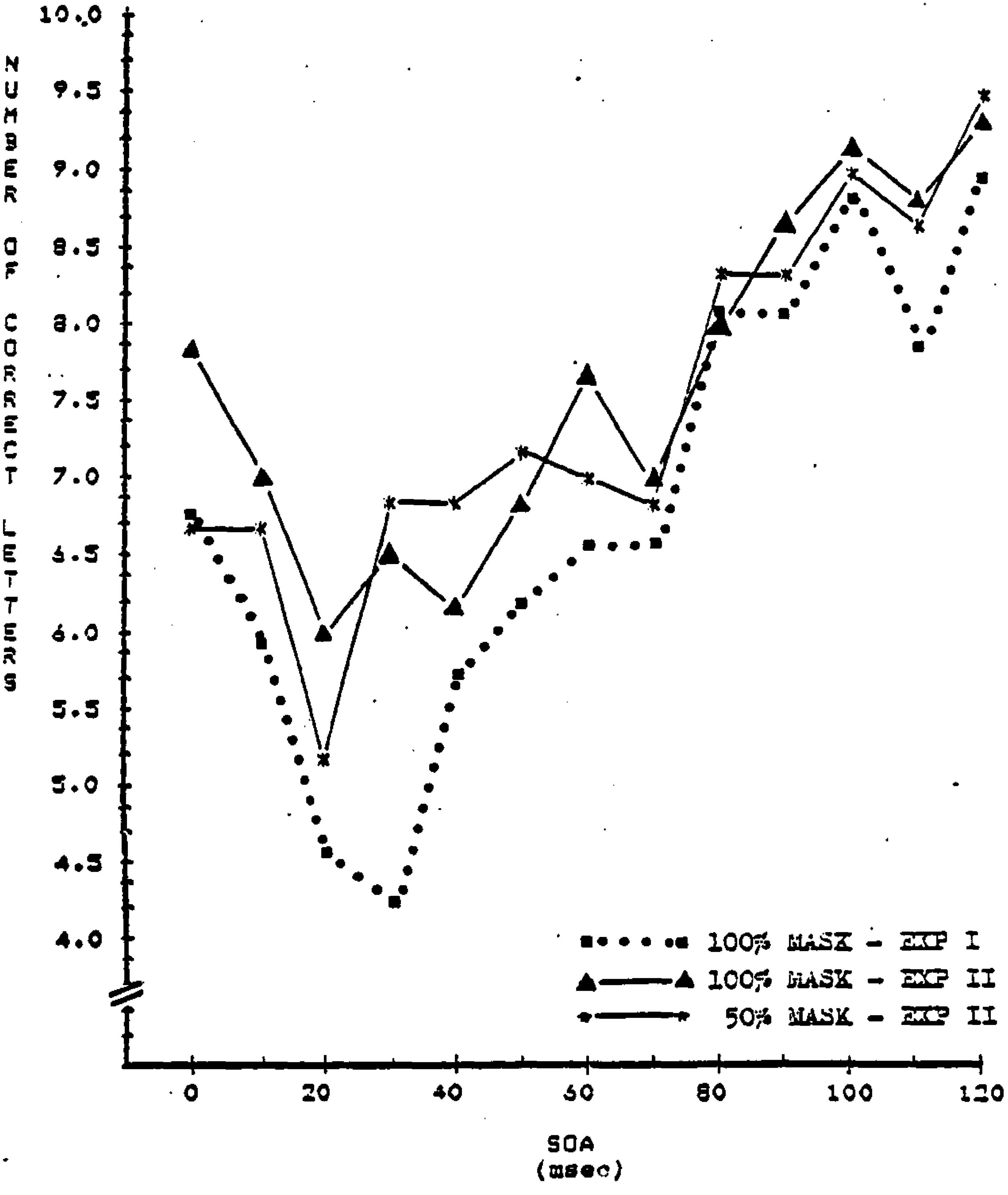
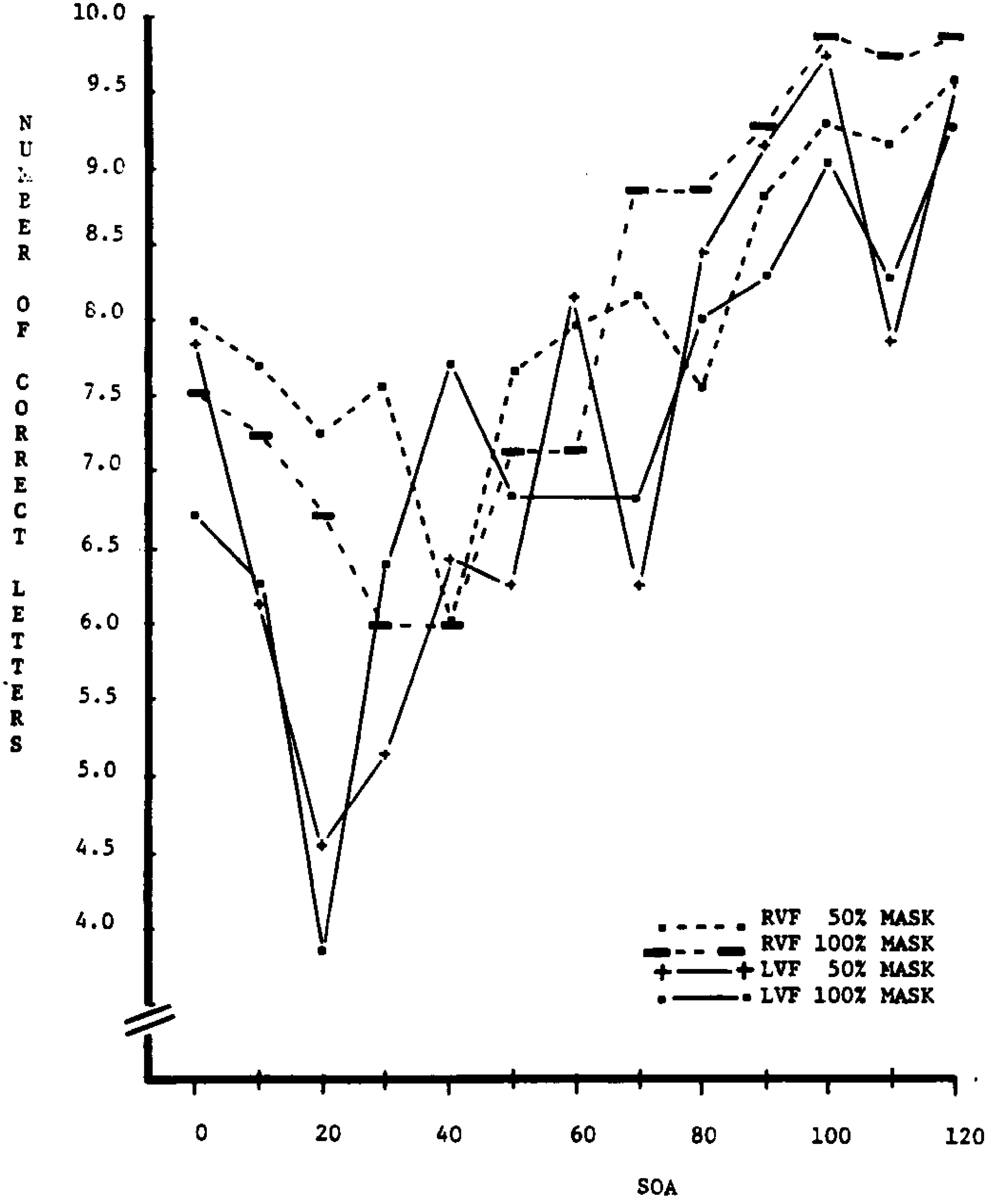

NUMBER OF CORRECT LETTERS
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
0
20
40
60
80
100
120
SOA
(msec)
100% MASK - EXP I
100% MASK - EXP II
50% MASK - EXP II

Figure 8


NUMBER OF CORRECT LETTERS
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
0
20
40
60
80
100
120
SOA
RVF 50% MASK
RVF 100% MASK
LVF 50% MASK
LVF 100% MASK