The Effect of Alerting Signals on Left Brain Damaged (Aphasic) and Normal Subjects' Accuracy and Response Time to Visual Stimuli

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REVIEW

It has been demonstrated with normal subjects that utilization of a forewarning period arouses subjects and facilitates the reception of incoming stimuli (Posner and Klein, 1973; Posner and Bores, 1971; Bertelson, 1967; Lansing, 1959). In each of the above investigations, a warning signal was used to obtain faster subject reaction times. It has also been suggested (Neisser, 1967) that readiness also improves the perceptual performance of normal subjects. Subject readiness has traditionally been studied with differing forewarning periods preceded by a warning signal. In investigations of hearing thresholds, Treisman and Howarth (1959) and Howarth and Treisman (1961) found that their subjects' auditory thresholds could be reduced with the utilization of a warning signal. These authors concluded that allowing a subject to prepare or ready himself for a signal will enhance the detection of that signal.

The utilization of differing forewarning periods also has allowed the scientific measurement of optimal time intervals between a warning signal and a stimulus (Lansing, 1959; Bertelson, 1967). Lansing's (1959) findings demonstrated that visual reaction time without an alerting signal averages 280 milliseconds. When an auditory signal (buzz) preceded the visual stimulus, reaction times for his subject were reduced to approximately 206 milliseconds. For this decreased reaction time, the forewarning had to occur at least three-tenths of a second prior to the stimulus onset. Bertelson (1967) not only reached similar conclusions as to the impact of warning signals, but like Lansing (1959) demonstrated the significance of an optimal time interval between the presentation of a warning signal and stimulus onset on subject performance. Bertelson incorporated seven forewarning periods ranging from 20 to 200 milliseconds. His findings suggested that it takes between 100 to 150 milliseconds to obtain the full effect of a warning signal on subject reaction times. The results of these studies support the view that the warning signal's possible function is that of a time cue to begin preparatory adjustments just before the expected time of stimulus presentation (Broadbent and Gregory, 1961; Hershenson, 1962; Walter, 1964; Karlin, 1970; Welford, 1973; Posner and Klein, 1973). Normal subjects appear to get into an aroused condition which, when preparing to deal with information, enhances reception from any source. This facilitation is illustrated in track and field events wherein an official precedes a race with preparatory instructions, such as "get ready, get set." This time preceding the physical act allows the runners to prepare themselves and facilitate beginning the race with the fastest time possible from the starting line for each runner. In processing an input, facilitation probably occurs as the result of the expectancy generated by a person when preparing to deal with information. Fitts and Posner (1967) stated that the most optimal way to prepare for any input is to first generate an expectancy of the event. Accordingly, this expectancy will facilitate the processing of incoming inputs efficiently and accurately by specifying which stimulus is to be processed in memory.

Investigations in neurophysiology have also been directed to the time interval between a warning signal and a stimulus, using electroencephalographic techniques. Karlin (1970) demonstrated a heightened state of arousal or readiness which was maintained by subjects following a warning signal. The results of this study of expected versus unexpected inputs indicated that as long as a subject knows when the next stimulus will occur, he will ready himself to process relevant stimuli and allocate fewer resources to incidental attention to irrelevant, secondary inputs. Walter (1964) and Näätänen (1967) demonstrated enhanced evoked potentials when preparation for relevant stimuli was made possible via a warning signal.

In attempting to describe the anatomical composition of the alerting system, Lindsley (1961) suggested that the reticular activating system may serve as a general arousal mechanism. This notion was supported by clinical observations offered by Luria (1958); Miller, Canter and Pribram (1960); and Schuell (1964). These authors hypothesized that the interaction between preparation and the reticular formation was that the reticular formation's principle function was to participate in and oversee the initiation and execution of plans.

Researchers such as Kahneman (1973) and Glass, Holyoak, and Santa (1979) studied the existence of low arousal resulting from brain injury by examining subjects with chronic conditions of low arousal levels. This difficulty may manifest itself in the form of a processing impairment which is free from any language deficit. These authors suggest that subjects in a low state of arousal may have difficulty adapting to tasks by not permitting the system the time for modulation of resource allocation to insure efficient information processing.

Past investigations in speech and language pathology have focused on scientifically measuring and describing the characteristics of the input stimuli. Research studies in aphasia have manipulated many aspects of input stimuli such as length (Weidner and Lasky, 1976; Skelly, 1975; Holland and Sonderman, 1974; Shewan and Canter, 1976), mode of stimulation (Rosenbek, 1978; Lapointe and Horner, 1976), the effects of time variations on the stimuli (Skelly, 1975; Albert and Bear, 1974; Swinney and Taylor, 1971; Rolnick and Hoops, 1969) and the role of context (Shewan, 1976; Podraza, 1975; Wiig and Globus, 1971; Weigl, 1968, 1973). These studies of the input stimulus appear to be among the most researched areas in aphasia, while relatively few investigations have been concerned with the effects of forewarning periods preceded by warning signals on aphasic subjects' performance. It appears evident, however, that certain types of brain injury do result in attention or arousal impairments. When an aphasic patient misses the beginning portions of messages, the deficit might be due to the preparatory, anticipatory or attentional strategies already described. Porch (1967) and Brookshire (1973) describe aphasic impairments which are characterized by an auditory deficit known as slow rise time. The patient with slow rise time has a tendency to miss the initial portions of incoming stimuli. This appears to be due to the auditory processing system requiring a longer than normal period of time to shift to an active state.

Critchley (1970) and DeRenzi and Faglioni (1965), postulate that the reception of input signals is imperfect and somewhat delayed in aphasic individuals and that the impairment may reflect the patient's inability automatically to generate expectations. As described earlier, expectations about incoming stimuli regarding stimulus onset assists in the correct reception of input signals. These authors stress the importance of measuring attention in testing for aphasia because aphasia may entail an impairment of this prior set.

There are a few investigations in aphasia that point toward the importance of prestimulus facilitation. Green and Boller (1971) demonstrated that in severely aphasic patients, responsiveness was enhanced when the presentation of a stimulus was accompanied by an introductory word, phrase or sentence. More recently, Marshall andThistlethwaite(1977) studied the effects of different types of alerting devices with 10 aphasic patients. The results of this study indicated that a warning signal was advantageous to auditory comprehension in adult aphasics as measured by the Token Test (1962). Marshall andThistlethwaite described,as did Green and Boller, a need for prestimulus warning but neither investigation defined the best time interval between the warning signal and stimulus onset.

It was the purpose of this investigation to measure and study the effects of five different forewarning periods on subject accuracy and reaction time to a same-different stimulus comparison. The following question was asked. What are the effects of the presentation of a prestimulus warning signal at 0 (no warning signal), and at 0.5, 1.0, 1.5, 3.0 seconds pre-stimulus on aphasic and normal subject accuracy and reaction time to a same-different stimulus comparison task?

METHOD

Subjects. Subjects for this investigation were 15 left-brain-damaged (aphasic) and 15 normal adults. All subjects in the left-brain-damaged (aphasic) group met the following selectional criteria. Each subject was at or above the 50th percentile on the Porch Index of Communicative Ability (Porch, 1967); each subject had left brain damage as confirmed by three of the following four procedures: abnormal angiogram, abnormal motor signs, abnormal cat scan, and abnormal brain scan. Any subject who exhibited right hemisphere brain damage was excluded from this study. In addition, each left-brain-damaged subject showed no more than a 30 dB HL hearing level, had sufficient visual acuity and understanding of the concept of "same" or "different" as measured by stimulus comparison pretrials.

All subjects who were included in the normal group met the following criteria. Each subject was at or above the 92nd percentile on the Porch Index of Communicative Ability (PICA); showed no more than a 30 dB HL hearing level; had adequate visual acuity and understood the concept of "same" or "different" as measured by stimulus comparison pretrials. In addition, all subjects in the normal group made no errors on the Left-Right Discrimination Test (Boone and Prescott, 1968).

Warning Signal, Experimental Conditions and Stimuli. The warning signal for this investigation was a 750 Hz signal presented at 70 dB HL for a 0.5 second duration. The signal was presented through earphones bilaterally.

Five experimental warning signal interval (WSI) conditions were used between the warning signal and stimulus onset. These intervals, which each subject received randomly, were 0 seconds (no warning signal); 0.5 seconds; 1.0 seconds; 1.5 seconds and 3.0 seconds.

The stimuli for this investigation were 300 picture pairs which were similar in size, shape and coloring. Each picture was taken from the Denver Auditory Sequencing Test (Aten, 1979). There were five sets of 60 picture pairs, one for each of the five experimental conditions. Each set of 60 picture pairs was randomly presented "same" or "different" in each of the five experimental (WSI) conditions. Each picture pair had a visual exposure duration of 3 milliseconds.

Apparatus. All procedures, except for the PICA, Left-Right Discrimination Test and hearing test, were carried out in a sound treated room. Within the sound room was a 6' x 2.5' x 2.5' compartment with the interior painted black, except for a 6" x6" viewing screen, which was used by each subject for viewing the picture stimuli (Figure 1). These stimuli were projected at a 10° angle, five feet from the subjects.

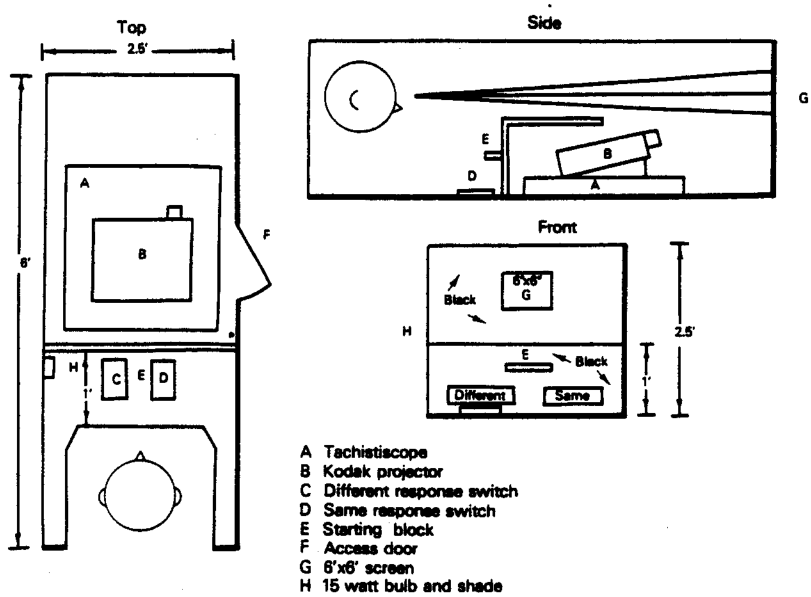

Figure 1. Subject viewing compartment: top, front, side, and interior views.

The warning signal tone (Figure 2) was generated by a (General Radio Company, 1302-A) signal generator. The tone was initiated by an electronic switch (G&S, Model 829-C) which turned the tone on and off in response to an impulse from the timing circuit (Gerbrands, Model G1171). The tone's intensity was controlled by an attenuator (Hewlett-Packard, Model 350-BB). A matching transformer was also utilized to transform a compatible signal to a mixer-splitter. The tone's duration was controlled by the timing circuit which also manipulated the time interval between the tone and stimulus onset. After the interaction of the timing circuit, signal generator, electronic switch, attenuator, matching transformer and mixer-splitter was completed, the tone was presented to each subject through headphones

(TDH 39-102) bilaterally. After the presentation of one of five experimental WSI conditions, the timing circuit activated a slide projector (Kodak Carousel, Model 800) and controlled the duration of the stimulus exposure. The timing circuit then, on initiation of stimuli presentation, activated an electronic counter (Hewlett-Packard, Model 5302-A) to record the subject's response time. Each subject responded "same" or "different" by touching either a red switch or green switch mounted directly in front of the subject 4.5 inches apart. As a subject pressed either switch from a starting block handle mounted above the response switches, a response time was recorded. The activation of either switch also illuminated a red or green light emitting diode corresponding to the appropriate switch for recording of the subject's accuracy of response. Once a response was made, a 1.0 second time interval lapsed before the initiation of the next tone and/or stimulus. If no response was made, a six second time interval occurred between stimulus onset and presentation of the next tone and/or stimulus. This procedure continued for all 300 stimuli pairs presented and for all subjects.

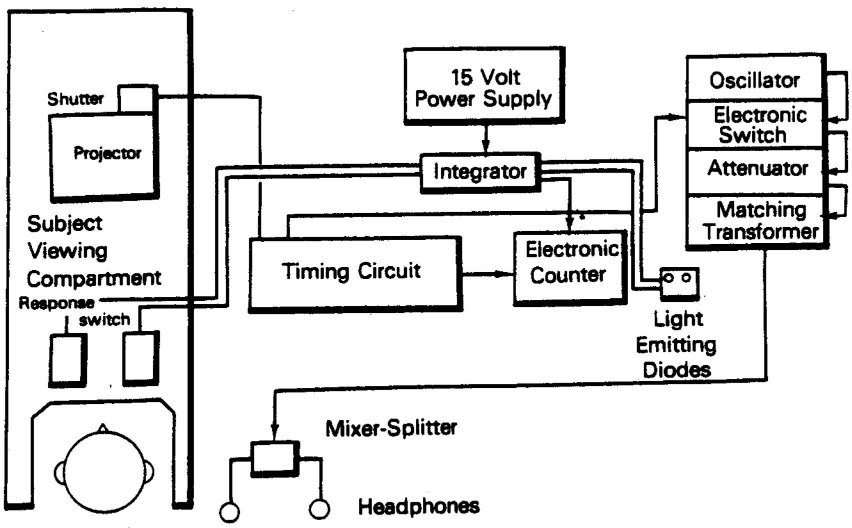

Figure 2. Apparatus layout.

<u>Procedure</u>. The following sequence of experimental procedures were carried out for this investigation. This sequence was maintained for all subjects who participated in the study. Each subject was initially given a PICA not more than two weeks preceding participation in the experiment. On the day of the experiment, all subjects who were considered normal were administered the Left-Right Discrimination Test. Each subject then received a hearing screening test and pretest trials. The pretest involved 20 picture pairs, which were not again utilized in the experiment, preceded by a 750 Hz tone of 70 dB intensity two seconds before stimulus onset. The subject responded in the same fashion as previously described.

On completion of the pretest, all subjects were given 300 random picture pairs to obtain the "same" or "different" response. These stimuli were preceded by the random ordered manipulation of the five experimental SWI conditions. The subjects responded "same" or "different" by pressing the appropriate lever.

RESULTS

Test-Retest Correlations. Correlation coefficients for test-retest indicated the existence of high correlations between test-retest runs for two subjects. Table 1 depicts these correlation coefficients for both accuracy and reaction time. These values were interpreted to represent acceptable levels of test-retest reliability.

Table 1. Summary of correlations of accuracy and reaction time for test-retest.

Category Description Between Tests One and Two		Pearson Product Moment Correlation Coefficient
Subject #1	Accuracy	.964*
Subject #1	Reaction Time	.962*
Subject #2	Accuracy	.970*
Subject #2	Reaction Time	.943*

*Significant at $p < .05$

Stimulus Item Analysis. A Z score transformation for the mean number of errors for each item revealed that of the 60 visual stimuli pairs, only two were markedly different from the other stimuli. These two items fell beyond $\pm$ 1.5 standard deviations from the mean.

Accuracy. To establish whether or not mean accuracy of response differences existed between the five experimental WSI conditions (Factor A), as well as for the existence of any group differences (Factor B), and for the existence of an interaction effect, all test accuracy results were subjected to a Two Factor Repeated Measures Analysis of Variance procedure. As seen in Table 2, statistically significant ($p < .05$) differences were found between the five SWI conditions, the two groups studied, and the interaction of Factor A with Factor B. Figure 3 illustrates the difference in each group's mean performance for each of the five WSI conditions. The total accuracy mean for the left brain damaged group across conditions was 43.93 items correct while the normal group mean accuracy performance across conditions was 47.54 items correct.

Reaction Time. A Two Factor Repeated Measures Analysis of Variance procedure was also applied to these data to determine whether or not any reaction time differences existed between each of the five experimental WSI conditions (Factor A); or for differences between group reaction times (Factor B); and to determine whether or not any interaction occurred between the experimental WSI conditions and the two groups. As seen in Table 3, statistically significant ($p < .05$) differences were noted for Factor A as well as for Factor B. No statistically significant (.05) interaction effect was observed.

Table 2. Summary of analysis of variance for group accuracy and experimental conditions.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	Error Term	F
Accuracy Between Conditions	2161.827	4	540.457	2	39.185*
Brain Damage by Normal	489.607	1	489.607	1	4.769*
Condition Accuracy by Group	196.627	4	49.157	2	3.564*
Error Terms					
Subjects Within Groups (1)	2874.053	28	102.645		
Condition Accuracy x Subjects Within Groups (2)	1544.747	112	13.792		

*Significant at $p < .05$

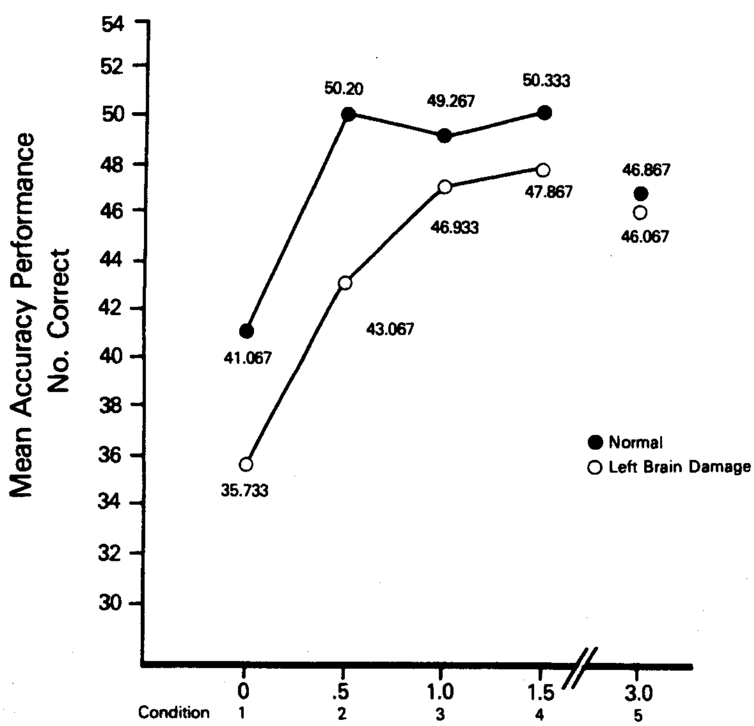

Figure 3. Accuracy means of each group for all experimental warning signal conditions.

Table 3. Summary of analysis of variance for group reaction time and experimental conditions.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	Error Term	F
Reaction Time Between Conditions	4.218	4	1.054	2	19.5707*
Brain Damage by Normal	8.448	1	8.448	1	13.5577*
Condition RT by Group	.133	4	.033	2	.6189
Error Terms					
Subjects Within Group (1)	17.447	28	.623		
Conditions by Subjects Within Groups (2)	6.035	112	.054		

*Significant at $p < .05$

To determine the locus of the statistically significant ($p < .05$) differences between WSI condition means, a Tukey procedure (Glass and Stanley, 1970) was applied (Table 4). The results demonstrated statistically significant ($p < .05$) differences between the no WSI condition and the 0.5 second WSI condition, the 1.0 second WSI condition, and the 1.5 WSI condition. These levels of performance are depicted in Figure 4.

Table 4. Tukey Test for significant gap between experimental condition means for all subjects.

Warning Signal		0	.5	1.0	1.5	3.0
	Mean	1.8628	1.4751	1.4039	1.4229	1.5377
0	1.8628		.3877*	.4589*	.4399*	.3251
.5	1.4751			.0712	.0522	.0626
1.0	1.4039				.019	.1338
1.5	1.4229					.1148
3.0	1.5377					

Significant gap ($p \leq .05$) = .3325

*Significant at $p < .05$

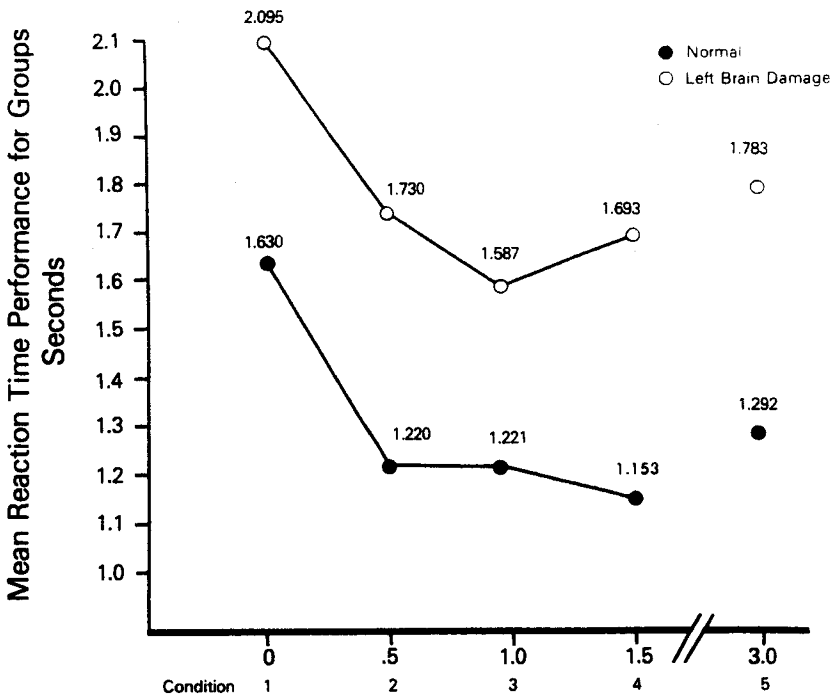

Figure 4. Reaction time means of each group for all experimental warning signal conditions.

DISCUSSION

These results indicated that both normal subjects' and brain damaged subjects' accuracy and reaction times to visual stimulus comparisons were facilitated by the use of a warning signal. For accuracy in the normal group, the full effects of the warning signal were seen when the warning signal preceded the visual stimulus by 0.5 to 1.5 seconds. The brain damaged group began to show the effects of the warning signal at 0.5 seconds but did not experience the full impact of the warning signal on accuracy until 1.0 to 3.0 seconds preceded stimulus onset. It appeared that the pathologic group needed more warning time for optimal facilitation of accuracy to take place. This finding appears to support Wepman's (1951) "shutter principle" hypothesis which suggests that delays imposed on left-brain-damaged adult performance are likely to be a result of the individual's inability to move the processing system to an active state as quickly as normals do. The normal group's accuracy began to deteriorate when 3.0 seconds preceded stimulus exposure, while the brain damaged group showed a stabilization of performance and maintained high accuracy when more preparatory time was provided.

The results for reaction times indicated that both groups performed with similar patterns of responses over the five experimental conditions. However, it was concluded that a warning signal that preceded visual stimuli by 0.5, 1.0 and 1.5 seconds significantly enhanced reaction time for all subjects studied, and that the aphasic subjects were generally significantly slower in responding than normals were.

To describe the results of this experiment for both subject accuracy and reaction time separately would limit the scope of the present study. Pachella (1974) defined the relationship between accuracy, reaction time and subject performance in terms of the minimum amount of time needed for a subject to produce a majority of correct responses. When the obtained results for reaction time and accuracy in this investigation were examined together for left-brain-damaged subjects, there appeared to be a net gain in both spheres of performance when any one of the four WSI conditions were compared to the no WSI condition. In the pathologic group, the full impact of the warning signal on accuracy and reaction time was not evident, however, until the time between the alerting signal and stimulus exposure was between 1.0 and 3.0 seconds. These results further suggested that 1.5 seconds was the optimal time interval between an alerting signal and stimulation. This condition was considered the best facilitator of accuracy and reaction time because the highest accuracy scores were noted in this condition, while the increase of 0.1 second latency from the 1.5 to 1.0 WSI condition was considered to be nonmeaningful. This increase in time was also considered not worth the decrease in average accuracy of 0.94 items correct between conditions.

For the normal group, the strongest effect of the alerting signal on accuracy and reaction time performance was present when 0.5 to 1.5 seconds were provided between the alerter and stimulus presentation. A 3.0 second WSI interfered with normal subject accuracy and had only a slight effect on reaction time. It appeared that an alerter that occurs 3.0 seconds before a stimulus provided normal subjects with too much time and had negative effects on performance. In contrast, the brain-damaged group maintained their performance in the 3.0 second WSI condition.

These findings support the notions of earlier research which described the need for additional preparatory time for the reception of an input by brain-damaged subjects. This investigation has demonstrated not only that preparatory time in excess of that needed by normal adults should be provided to left brain damaged adults, but also described optimal intervals of time between an alerting signal and stimulation. These findings appear to have direct clinical management benefits for assessment and treatment of left-brain-injured adults. The results of this investigation imply that when describing a patient's receptive and expressive skills for purposes of evaluation, it may be advantageous if a forewarning period prior to the stimulus used in the assessment interaction is presented. By utilizing a warning signal, a clinician might be able to describe the patient's optimal performance in terms of both accuracy and reaction time. It appears that alerting a subject allows additional time for the preparation of the patient's system to receive an input. It seems likely that assessment should incorporate forewarning periods, in addition to examining without warning signals, to establish optimal performance for a patient.

The results of this investigation also imply that when treating a patient with aphasia, it might be advantageous first to establish an optimal forewarning period (probably 1.5 seconds). As the patient improves, systematic reductions in time between warning signal and stimulus would be appropriate. A series of short-term goals oriented toward reducing the alerting signal interval to a more functional level could be part of the overall clinical program. This reduction could terminate with a self-cueing strategy by which the patient readies himself to receive and respond to an input.

The present study appears only to be the beginning of an area that needs further investigation. Further research could incorporate additional WSI's (WSI's longer than three seconds) and controlled reduction of WSI's. Such research might contribute to experimental treatment paradigms, and supplement the present data base in this area.

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