

PROCESSING TIME AS INFLUENCED BY THE NUMBER
OF ELEMENTS IN THE VISUAL DISPLAY

by

R. C. Atkinson, J. E. Holmgren, and J. F. Juola

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Processing Time as Influenced by the Number
of Elements in the Visual Display¹

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Abstract

In a visual detection experiment, a display of several letters was presented, and S was to report the presence or absence of a given target letter. Results clearly are incompatible with a self-terminating visual scanning process as hypothesized by Sternberg (1967). Two models are considered, a serial exhaustive scanning process and a parallel exhaustive process, but findings from the present study do not provide a basis for differentiating between them.

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In several experiments Estes and Taylor (1964, 1966) have studied the visual detection process for the case in which S searches for one of a predesignated pair of letters (signal or critical elements) imbedded within a tachistoscopically presented display of noise letters. A forced-choice design was used with S responding that he saw one or the other of the critical elements on every trial, even if the detection was uncertain. The models proposed to account for the results assume S samples a proportion of the letters present on each trial, and then serially scans through them to determine which target letter was included in the display. If the target letter is among the letters sampled, S makes the appropriate response after processing the critical element. If, however, the target letter is not included among the elements sampled on that trial, S guesses one of the two alternatives. These models accurately predict an increase in error rate with an increase in the number of noise elements in the display, but a deeper analysis of the scanning process is difficult to achieve using their data primarily because of the somewhat random placement of letters within the display and the lack of latency measures.

By measuring response latencies in a similar experiment Estes and Wessel (1966) were able to demonstrate that error latencies remain essentially constant across display sizes, indicating that S continues processing elements in searching for a match with one of the target letters until some temporal criterion is reached (perhaps the point at which the registered image of the display has decayed beyond usefulness in extracting information), at which point S guesses. The data also indicated that the search process might terminate with a correct response as soon as the target letter is processed. Estes and Wessel based both

of these latter inferences upon latency data that had been corrected for guessing, admittedly leaving definite conclusions about the nature of the scanning process for further research.

Using a different paradigm Sternberg (1966) has presented evidence for serial and exhaustive scanning of elements stored in memory. On each trial S was given a list of one to six digits to remember. A single test digit was then presented, and S responded by pulling an appropriate lever to indicate whether or not the test digit matched any of those in memory. In this experiment there were virtually no errors, allowing latency scores to be used without correction. Plotting latency against memory set size, Sternberg was able to draw two important conclusions:

- (a) The data could be fit by a straight line indicating a constant increase in latency for each additional item in the memorized list.
- (b) Independent of the size of the memory set, positive and negative responses take essentially the same amount of time. This suggests that comparisons are made exhaustively between the test element and memory elements; i.e., even when a match is obtained the scan continues to the end of the list before a response is made.

Sternberg (1967) has expanded the initial experiment to include variations in the number of display elements as well as the number of elements in memory. On each trial S was presented with anywhere from one to four digits to remember, and then was shown a tachistoscopic display containing one, two, or three digits in a linear array. The S was instructed to make a positive response if the two sets had any elements in common, and a negative response if no elements in the two lists matched. From the response latency data Sternberg concluded that S

begins the scan by comparing one item in the display with all memory items. After this comparison has been completed, a positive response is made if a match was detected; otherwise, another display item is selected and the comparison process is repeated. Thus, each scan of the memory list is exhaustive, while the scan of the display items is self-terminating. These conclusions were based on the observation that as the length of the memorized list increased, latencies for negative responses increased at a faster rate than those of positive responses for all display sizes greater than one item.

Support for Sternberg's (1967) representation of the scanning process has been offered by Nickerson (1966). In a task similar to Sternberg's paradigm, Nickerson found evidence for a self-terminating search for a target letter in a visually presented display. His data showed latencies to be inversely related to the number of elements that the memory and display lists had in common. Assuming a strictly serial comparison process, these results are incompatible with those predicted by an exhaustive scanning model. Nickerson points out that the high percentage of false negative responses in his study suggests that the search may terminate with a negative response after a certain amount of time has elapsed rather than terminating with the processing of a critical element in all cases. Although Sternberg does not report the percentage of false positive responses in his study, the same consideration may apply to that data.

Nickerson (1966) also tested for the effects of extended training on performance in the detection task. The results showed that both overall latency as well as the relative increase in latency with increasing

display size tended to decrease with practice and continued to decrease through 22 consecutive daily sessions.

For the present study it was decided to apply the Sternberg (1966) paradigm to a visual detection task like that of Estes and Taylor (1964, 1966) with the following modifications incorporated from both types of experiments: (a) A yes-no detection task was used rather than a forced-choice design to allow comparison of positive and negative responses. (b) The display letters were presented in a linear array with a relatively long exposure time to insure correct responding. This made it possible to use response latencies as the dependent variable, while eliminating the need to correct for guessing. (c) The Ss were run for several sessions to obtain sufficient data to examine individual performance and to determine the extent of practice effects. With these modifications it was hoped that the present study would lead to a more direct analysis of the scanning process.

METHOD

The Ss were eight female Stanford University undergraduates with normal vision. Each was paid a total of \$15.75 for the nine sessions of the experiment. In all sessions the task was to scan a visually presented array of letters to determine the presence or absence of a specific letter. The 20 consonants were used for both the target letters (critical elements) and the non-target letters (noise elements). The critical element was included in the display on half the trials.

The display slides were prepared from photographs of capital letters typed with an IBM Executive "Registry" electric typewriter. A dollar sign was used as a delimiter on each side of the display, with no

additional spaces between the signs and the display letters. The array of letters varied from one to five elements in length. Within each display length category, every consonant was used once at each serial position. With the additional constraint that no letter could appear more than once in a given display, 100 different slides were made. Because of the limited capacity of the slide projector, one display in each of the size categories was discarded to yield a total of 95 displays used in the experiment.

The apparatus employed included an automated dual tachistoscope previously described in a paper by Holmgren (1968). The displays were presented through a circular aperture onto a rear-projection ground glass screen, illuminating an area $2\frac{1}{16}$ in. in diameter. The displays measured $\frac{3}{16}$ in. in height and varied in length from $\frac{7}{8}$ in. for a display of size five to $\frac{3}{8}$ in. for a one-element display when projected on the screen. From a line of sight viewing distance of about 2 feet, the visual angle subtended by the largest display was approximately 2.2 degrees.

Between stimulus exposures the screen was illuminated by a second projector. A single pre- and post-exposure field was used containing four small black dots forming a rectangle $\frac{7}{8}$ in. by $\frac{1}{2}$ in. The display always appeared centered within this rectangle. The brightness of the pre- and post-exposure field, as measured by a Macbeth illuminometer, was 6.6 foot lamberts, while display brightness averaged 7.4 foot lamberts. Above the screen three small colored lights were arranged in a vertical row. Below the screen a single IEE Binaview character display unit was used to present the critical letter on each trial.

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The third part of the report discusses the future of work and the impact of automation and artificial intelligence. It examines the challenges posed by these technologies and the need for education and training to prepare workers for the future. The report also explores the potential for these technologies to create new jobs and economic opportunities.

The fourth part of the report discusses the future of energy and the impact of the transition to renewable energy. It examines the challenges posed by the current energy system and the need for investment in renewable energy technologies. The report also explores the potential for renewable energy to create new jobs and economic opportunities.

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The sixth part of the report discusses the future of health care and the impact of digital health and precision medicine. It examines the challenges posed by the current health care system and the need for investment in digital health technologies. The report also explores the potential for these technologies to create new jobs and economic opportunities.

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The tenth part of the report discusses the future of global governance and the impact of international organizations and global agreements. It examines the challenges posed by the current global governance system and the need for investment in global governance technologies. The report also explores the potential for these technologies to create new jobs and economic opportunities.

On a table in front of S, three telegraph keys were arranged along an arc extending from 9 o'clock to 12 o'clock. The keys were positioned so that S could rest her right arm comfortably on the table, with her right forefinger on the center key. By moving her hand along an arc 1 in. in either direction, S could depress either of the two response keys. The Ss were randomly assigned to two groups. Those in Group 1 registered a positive response (indicating a match between the critical letter and one of the display letters) by depressing the key nearest to them, and a negative response by depressing the key nearest the display. These conditions were reversed for Ss in Group 2.

The displays were presented in a different random order for each S and each session, with the constraint that each display size was shown equally often and each serial position contained the critical element equally often during the session. The target letter shown on each trial was chosen randomly from the set of non-display elements on negative trials and randomly from the set of display elements (with the above constraint) on positive trials. The sequence of positive and negative trials was random, with the restriction that there was an equal number of positive and negative trials during each session.

The following sequence of events occurred on each trial: (a) A single letter was presented for 2 sec. on the Binaview unit. (b) When the unit was turned off, S pushed a button held in her left hand and, after a .5 sec. delay, the display was presented for 400 msec. (c) Using her right hand S then made the appropriate response within a 2 sec. time limit after the onset of the display. (d) At the end of this period one of the three lights above the screen was turned on for 2 sec.; a green

1. The first part of the document discusses the importance of maintaining accurate records of all transactions and activities. It emphasizes that proper record-keeping is essential for transparency and accountability, particularly in financial matters. This section outlines the various methods and tools used to collect and store data, ensuring that information is readily accessible and secure.

2. The second part of the document focuses on the analysis and interpretation of the collected data. It describes the process of identifying trends, patterns, and anomalies within the dataset. This involves the use of statistical techniques and data visualization tools to present the information in a clear and understandable manner. The goal is to derive meaningful insights from the data that can inform decision-making and strategic planning.

3. The third part of the document addresses the challenges and limitations associated with data analysis. It highlights the potential for data bias, incomplete information, and the complexity of interpreting large datasets. The document provides guidance on how to mitigate these risks and ensure the reliability and validity of the analysis. It also discusses the importance of regular updates and reviews of the data to maintain its relevance and accuracy.

4. The final part of the document concludes with a summary of the key findings and recommendations. It reiterates the importance of a systematic and disciplined approach to data collection and analysis. The document encourages ongoing communication and collaboration between all stakeholders involved in the process, as well as a commitment to continuous improvement and learning from experience.

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light indicated a correct response, a red light indicated an error, and a white light indicated no response or a response made after the 2 sec. limit. After a .5 sec. intertrial interval, a new target letter was presented on the Binaview unit to start the next trial. Each trial lasted between 7 and 8 sec. depending on the elapsed time between the offset of the Binaview unit and the pressing of the start button by S.

The onset of the display triggered two latency counters, one stopping when S lifted her finger from the center key, and the other stopping when either the positive or negative response key was hit. In this way measures of release time and terminal response time were obtained.

The Ss were run for a total of 250 trials in each session. With a 5 min. rest period after the first 120 trials, the session lasted about 40 min. All Ss participated in nine sessions. Before each session Ss were instructed not to release the center key until they were certain of the correct response, and then to depress the appropriate key as rapidly as possible while being careful not to make errors. After each session S received feedback from E about her performance to insure rapid responding and a low error rate.

RESULTS

Mean latencies as a function of display size for both release responses and terminal responses are presented in Fig. 1. Release latency is the elapsed time between the onset of the display and the lifting of S's finger from the center key in initiating the terminal response. Terminal latency is the time between the onset of the display and the depression of the appropriate response key; i.e., release latency plus the additional travel time. Both release and terminal latencies were

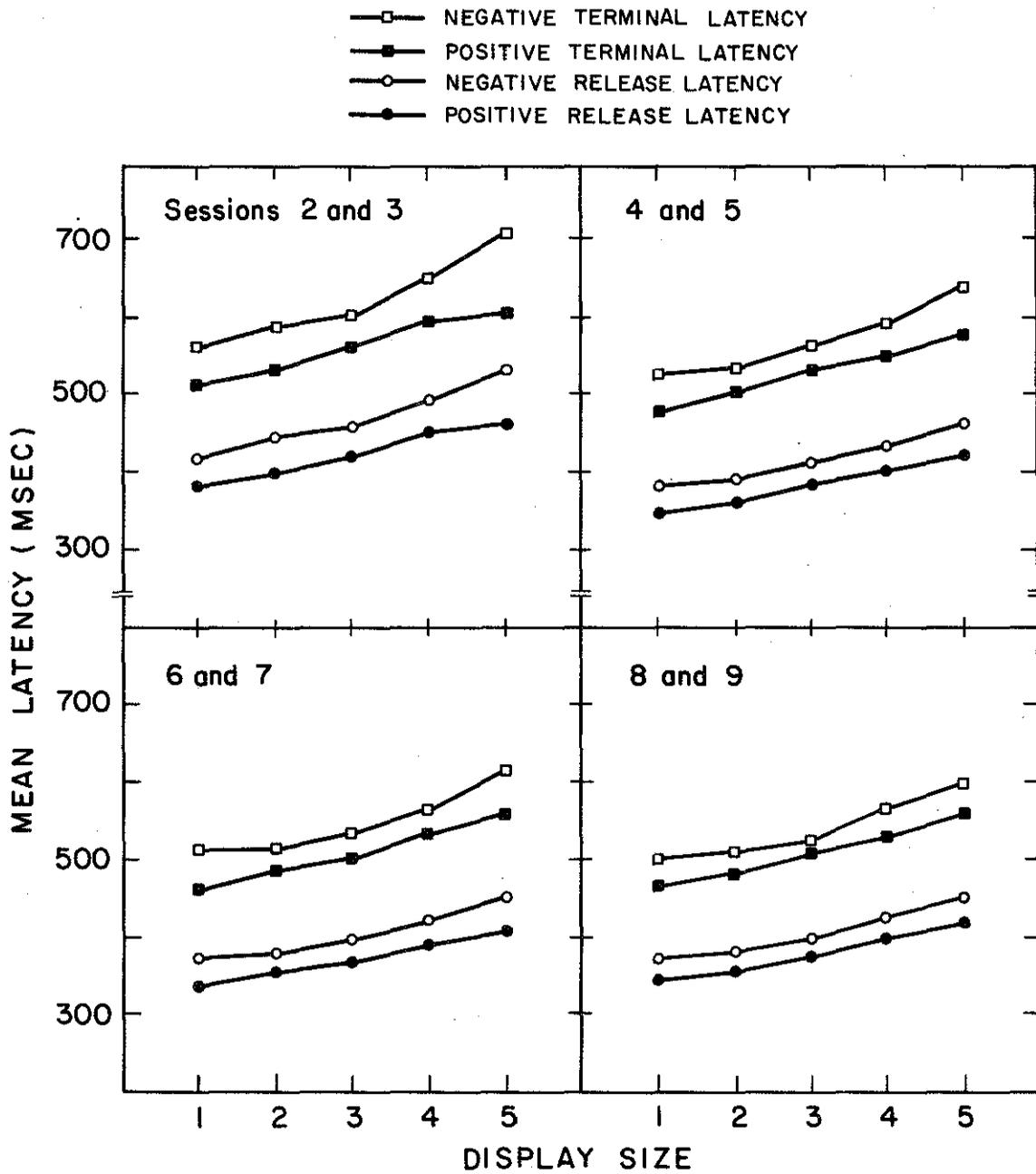


Fig. 1. Latency of positive and negative responses as a function of display size and session number for all Ss combined.

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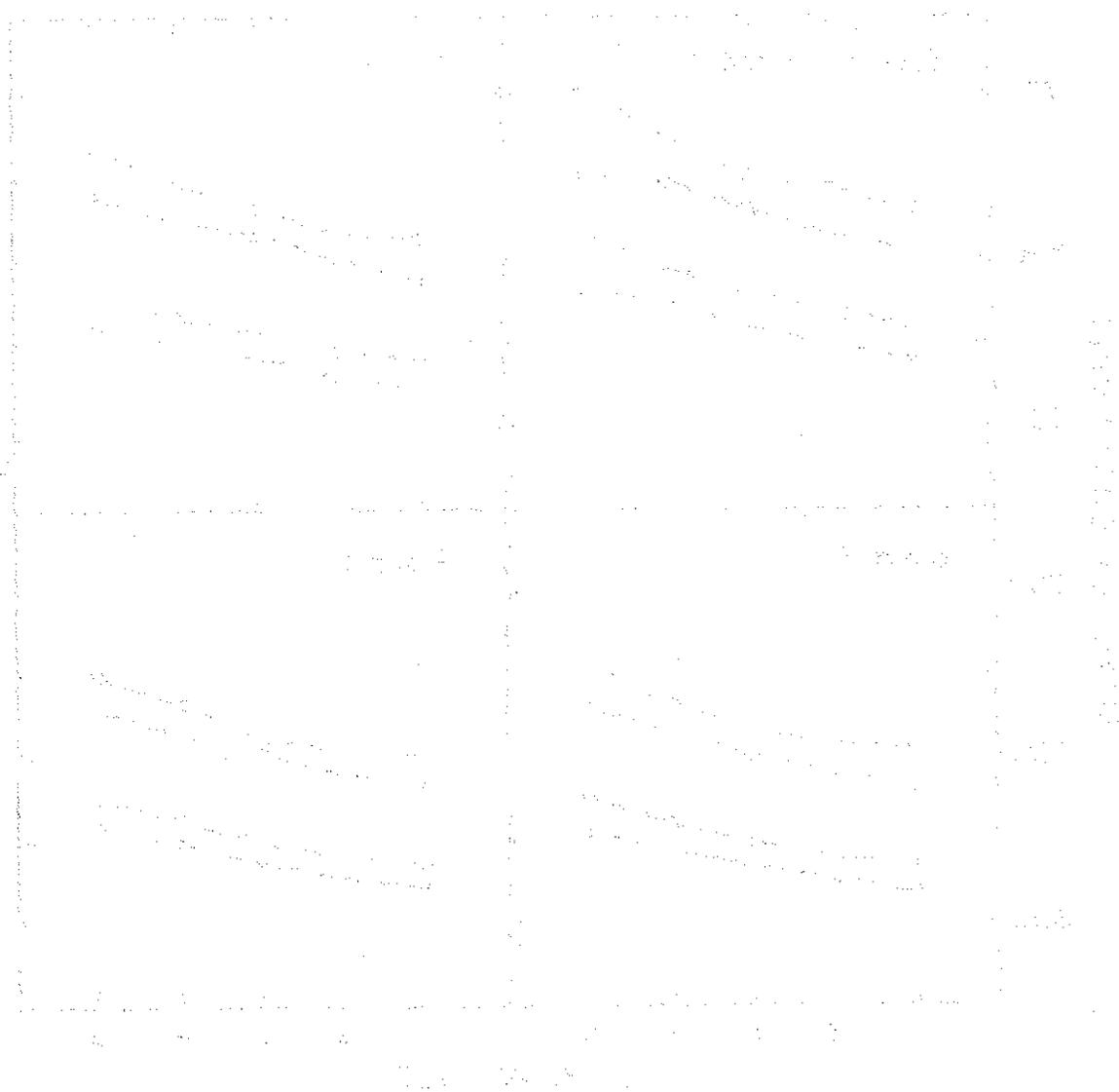


Figure 1. Comparison of experimental data (solid line) with theoretical calculations (dashed, dotted, and dash-dot lines) for the absorption spectrum of the sample.

recorded separately for positive and negative trials, and all latency data presented here are based upon correct responses only. Data from the first day were discarded, along with the first ten trials of each subsequent session. Data from sessions 2-9 were combined in pairs of consecutive days. Inspection of Fig. 1 suggests that latencies decreased over the first few sessions of the experiment, reaching a somewhat stable level by the fourth day. Consequently, further analysis was done on days 4 through 9 only.

Latencies as a function of display size are presented for Ss from Group 1 in the left panel of Fig. 2. The data for positive trials were further analyzed by plotting latency as a function of the serial position of the critical element within the display. The serial position curves for release and terminal latencies for each S are shown in the right panel of Fig. 2. Figure 3 presents similar data for Ss in Group 2. The data from both groups were combined, and the mean latencies are shown in Fig. 4. The error rate for each S and the standard deviations of response latencies are presented in Tables 1 and 2, respectively.

As can be observed in the left panels of Figs. 2-4, latency seems to be a linear function of display size. The best fitting straight lines were found for individual and grouped performance for positive and negative release latencies and positive and negative terminal latencies. The slopes and intercepts of these lines are presented in Table 3.

DISCUSSION

In a serial scanning process, if the mean processing time is the same for all items, response latency is an increasing linear function of the number of display elements. If the scan is self-terminating,

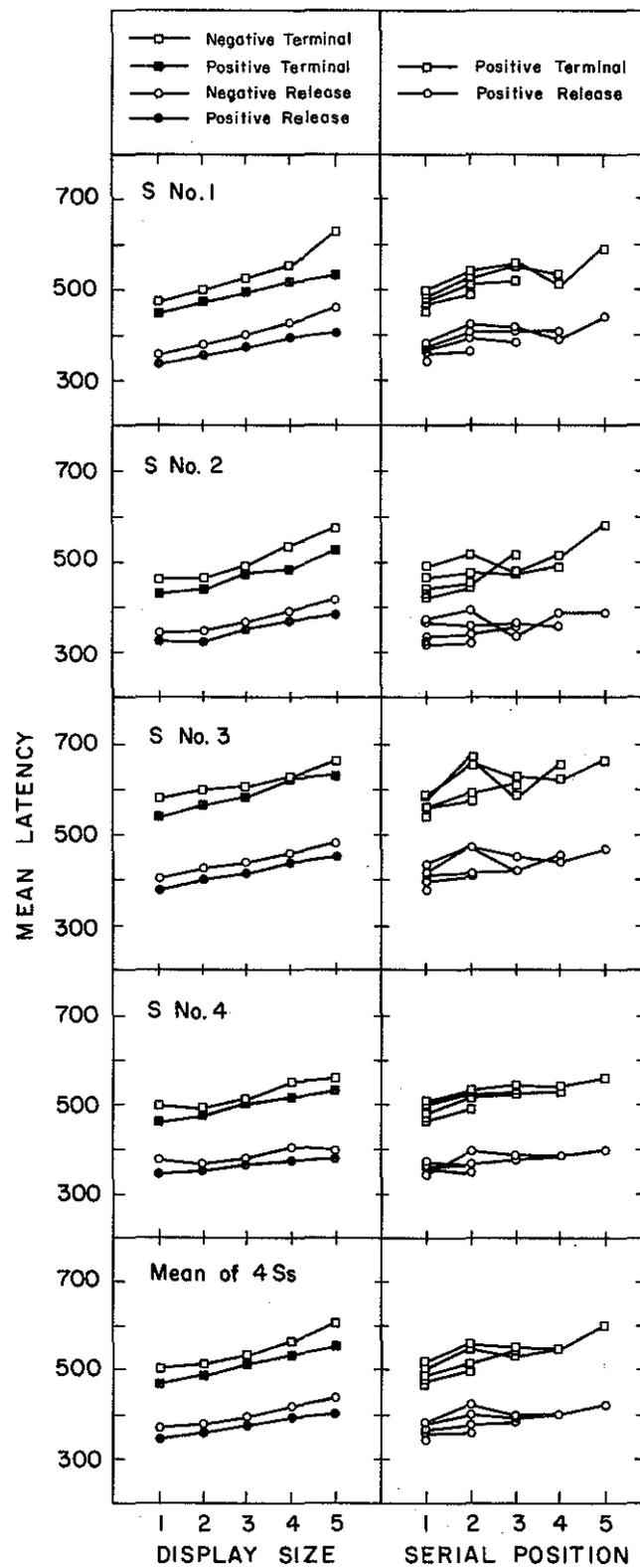


Fig. 2. Latency of positive and negative responses as a function of display size (left panel) and latency of positive responses as a function of the serial position of the critical element (right panel) for Ss in Group 1.

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The first part of the document discusses the importance of maintaining accurate records of all transactions. It emphasizes that every entry should be supported by a valid receipt or invoice to ensure transparency and accountability.

In the second section, the author details the various methods used to collect and analyze data. This includes both primary and secondary research techniques, as well as the use of statistical software to process large datasets.

The third section focuses on the results of the study. It presents a series of findings that indicate a significant correlation between the variables being tested. These results are supported by several charts and graphs that clearly illustrate the trends and patterns observed.

Finally, the document concludes with a summary of the key findings and offers some practical recommendations based on the research. It suggests that the insights gained from this study can be applied to improve existing processes and inform future decision-making.

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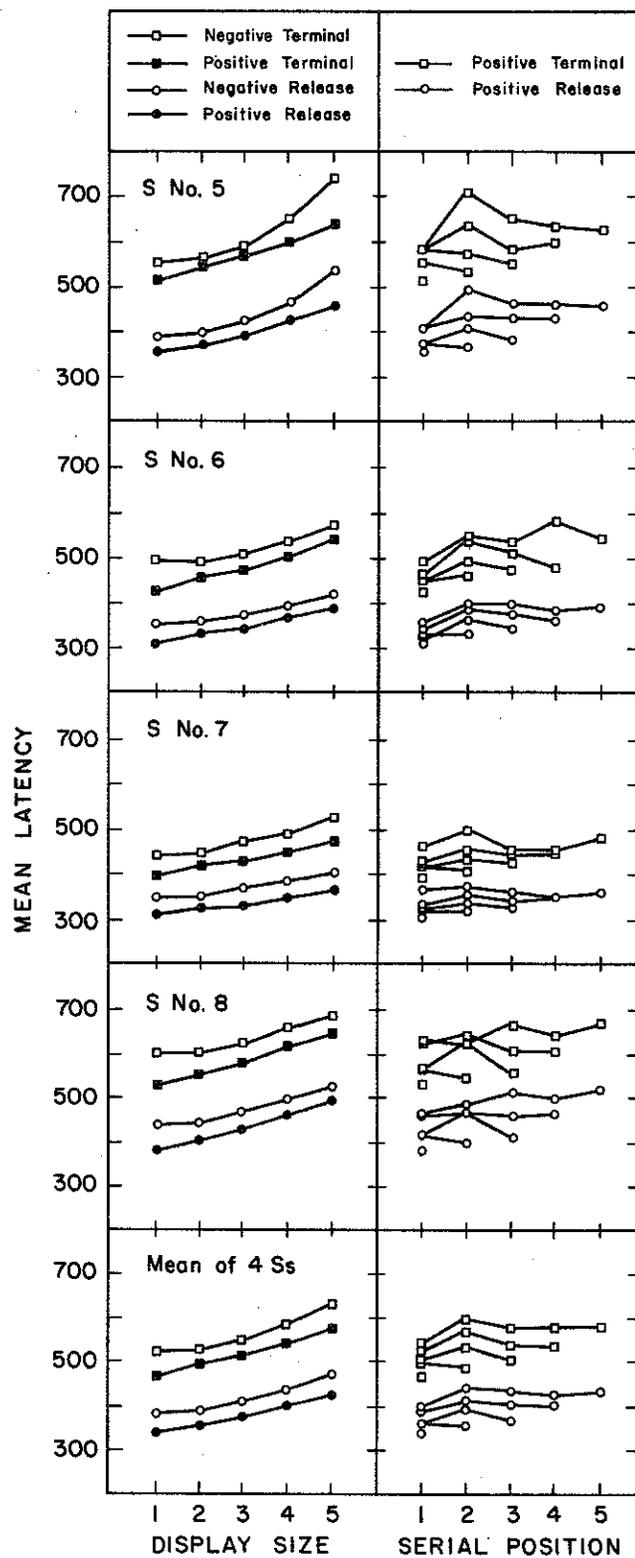


Fig. 3. Latency of positive and negative responses as a function of display size (left panel) and latency of positive responses as a function of the serial position of the critical element (right panel) for Ss in Group 2.

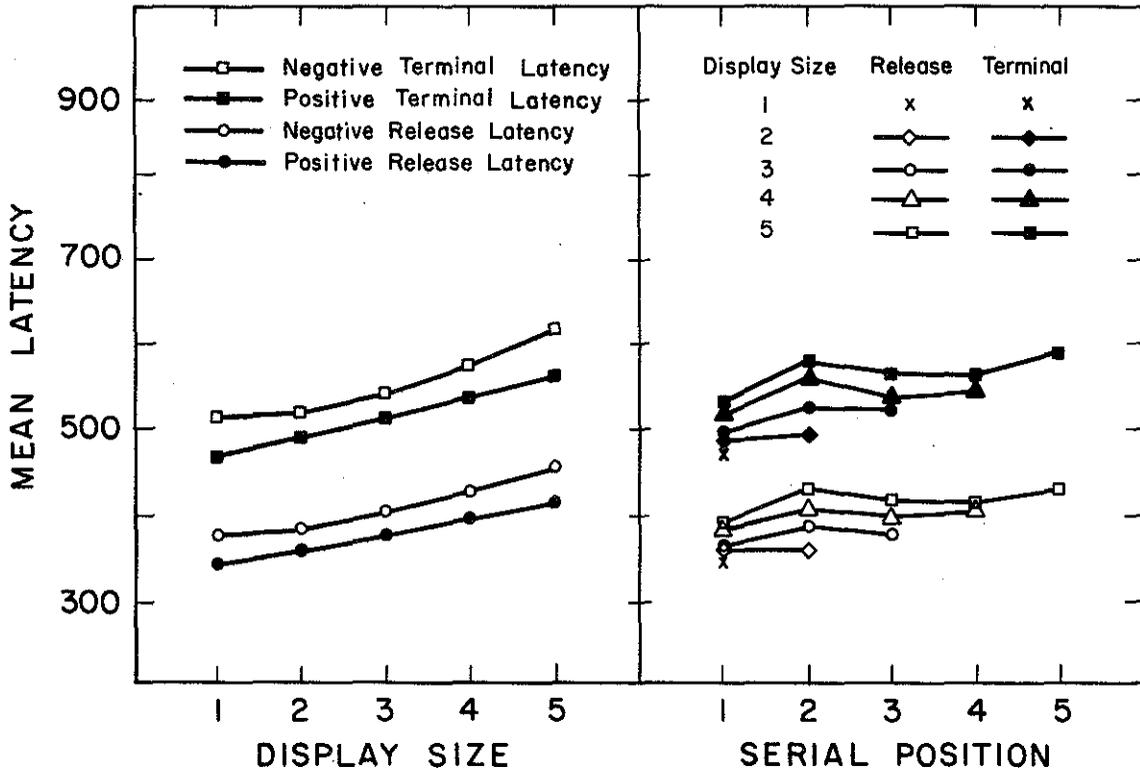


Fig. 4. Latency of positive and negative responses as a function of display size (left panel) and latency of positive responses as a function of the serial position of the critical element (right panel) averaged over all Ss.

1. The first part of the document discusses the importance of maintaining accurate records of all transactions. This is essential for ensuring the integrity of the financial data and for providing a clear audit trail. The records should be kept up-to-date and should be accessible to all relevant parties.

2. The second part of the document outlines the procedures for handling incoming payments. It is important to ensure that all payments are recorded promptly and accurately. The procedures should include verifying the amount and source of the payment, recording it in the appropriate ledger, and issuing a receipt to the payer. This process should be repeated for all payments received.

3. The third part of the document describes the process for making outgoing payments. It is important to ensure that all payments are made accurately and on time. The procedures should include verifying the amount and recipient of the payment, recording it in the appropriate ledger, and issuing a receipt to the recipient. This process should be repeated for all payments made.

4. The fourth part of the document discusses the importance of reconciling the accounts. This involves comparing the records of the business with the records of the bank and other financial institutions. This process should be performed regularly to ensure that the records are accurate and to identify any discrepancies. Any discrepancies should be investigated and resolved promptly.

5. The fifth part of the document outlines the procedures for preparing financial statements. These statements provide a summary of the financial performance of the business over a period of time. The procedures should include gathering all the necessary data, calculating the various components of the statements, and presenting the results in a clear and concise manner. These statements should be prepared regularly and should be available to all relevant parties.

6. The sixth part of the document discusses the importance of maintaining accurate records of all assets and liabilities. This is essential for ensuring the accuracy of the financial statements and for providing a clear audit trail. The records should be kept up-to-date and should be accessible to all relevant parties.

7. The seventh part of the document outlines the procedures for handling incoming payments. It is important to ensure that all payments are recorded promptly and accurately. The procedures should include verifying the amount and source of the payment, recording it in the appropriate ledger, and issuing a receipt to the payer. This process should be repeated for all payments received.

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Table 1
 Proportions of False Positive (FP) and False Negative (FN)
 Responses for Each Display Size

Subject	Display size										Mean error rate for all display sizes	
	1		2		3		4		5			
	FP	FN	FP	FN	FP	FN	FP	FN	FP	FN	FP	FN
1	.015	-	.007	.014	.014	.038	.031	.034	.035	.028	.020	.023
2	-	-	-	.013	.007	.008	.007	.042	.069	.021	.017	.017
3	.007	-	-	-	-	.023	-	.014	.028	.014	.007	.009
4	-	-	.007	-	.027	.056	.024	.097	.044	.088	.020	.048
5	.007	.006	-	-	.007	.013	.008	.029	.008	.035	.006	.017
6	-	-	-	-	-	.007	-	.007	.008	-	.002	.003
7	.014	-	.029	.029	.007	.020	.028	.007	.028	.043	.021	.020
8	-	-	.007	.007	.007	.023	.014	.038	.023	.008	.010	.015
Group 1	.006	-	.005	.007	.012	.031	.016	.047	.044	.038	.017	.025
Group 2	.005	.002	.009	.009	.005	.016	.012	.020	.017	.022	.010	.014
Overall means	.005	.001	.006	.008	.009	.024	.014	.034	.030	.030	.013	.019

1. The first part of the document discusses the importance of maintaining accurate records of all transactions and activities. It emphasizes that proper record-keeping is essential for transparency and accountability, particularly in financial matters. This section also outlines the various methods and tools used to collect and analyze data, ensuring that the information is reliable and up-to-date.

2. The second part of the document focuses on the implementation of these practices across different departments and projects. It provides detailed instructions on how to set up systems for data collection and analysis, including the selection of appropriate software and the training of staff. This section also addresses the challenges that may arise during the implementation process and offers strategies to overcome them.

3. The third part of the document discusses the importance of regular communication and reporting. It highlights the need for clear and concise reports that provide a comprehensive overview of the current status and any potential issues. This section also outlines the frequency and format of these reports, ensuring that all stakeholders are kept informed and can make informed decisions based on the available data.

4. The final part of the document concludes with a summary of the key points discussed and a call to action. It encourages all employees to take ownership of their data and to adhere to the established procedures. The document also provides contact information for any questions or concerns, ensuring that support is readily available.

Table 2

Standard Deviations of Response Latencies Across Subjects (in msec.)

		Display Size				
		1	2	3	4	5
Release	Positive	27.0	31.9	33.9	38.6	44.3
	Negative	32.1	35.0	36.9	40.2	52.4
Terminal	Positive	51.4	53.9	55.5	62.4	61.2
	Negative	55.2	58.1	54.4	58.5	69.7

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Table 3

Slopes (s) and Intercepts (t) of the Best-Fitting Straight Lines for Release Latency and Terminal Latency Data for Both Positive and Negative Responses

Subject	Release Response						Terminal Response					
	s ⁺	t ⁺	s ⁻	t ⁻	s ⁻ -s ⁺	t ⁻ -t ⁺	s ⁺	t ⁺	s ⁻	t ⁻	s ⁻ -s ⁺	t ⁻ -t ⁺
1	17.4	325	22.9	338	5.5	13	21.3	433	35.0	433	13.7	0
2	15.3	309	20.1	307	4.8	-2	22.4	398	28.7	413	6.3	15
3	18.6	363	18.7	386	0.1	23	23.1	520	18.8	561	-4.3	41
4	8.9	339	7.8	363	-1.1	24	17.8	446	18.0	469	0.2	23
5	25.4	325	35.7	336	10.3	11	29.6	486	45.3	484	15.7	-2
6	19.1	290	16.5	329	-2.6	39	27.7	395	19.0	462	-8.7	67
7	13.9	292	14.8	324	0.9	32	18.6	375	21.5	408	2.9	33
8	28.2	351	22.5	408	-5.7	57	29.8	496	22.9	564	-6.9	68
Group 1	15.0	334	17.4	348	2.3	14	21.2	449	25.1	469	4.0	20
Group 2	21.6	314	22.4	349	0.7	35	26.4	438	27.2	480	0.8	42
Overall means	18.3	324	19.9	348	1.5	25	23.8	444	26.2	474	2.4	31

the slope of the positive response function will be half that of the negative line because, on the average, only half of the elements in a positive display are processed before the target is detected. If the scan is exhaustive all elements will be processed on every trial, and the positive and negative functions will have the same slope. As can be observed in Table 3, the slopes for both positive and negative responses appear to be about the same, and (with the possible exception of S number 5) the scan is clearly not self-terminating. Another argument against the self-terminating hypothesis could be based upon the flatness of the serial position curves (right panels of Figs. 2-4). Given a strict self-terminating scan that begins with the element at the left side of the display and proceeds serially to the right, the serial position curves would all have the same slope and intercept. If, however, the scan begins at a random starting point within the display, the serial position curves would be flat and indistinguishable from those generated by an exhaustive scan. Therefore the obtained serial position curves cannot alone be taken to contradict a serial and self-terminating scanning model, but together with the obtained functions for positive and negative response data it may be concluded that despite some reports favoring the self-terminating model (Estes & Wessel, 1966; Nickerson, 1966; Sternberg, 1967), the evidence from the present study seems to invalidate that hypothesis.

In view of the apparent incompatibility between the present results and those obtained by Nickerson (1966) and Sternberg (1967), the data from the latter studies were examined for those conditions common to the present experiment. The results obtained by Nickerson and Sternberg

The first part of the document discusses the importance of maintaining accurate records of all transactions. It emphasizes that proper record-keeping is essential for the integrity of the financial system and for the ability to detect and prevent fraud. The document outlines the various types of records that should be maintained, including receipts, invoices, and bank statements. It also discusses the importance of regular audits and the role of internal controls in ensuring the accuracy of the records.

The second part of the document focuses on the importance of transparency and accountability in financial reporting. It highlights the need for clear and concise reporting that provides a true and fair view of the organization's financial performance. The document discusses the various methods used to calculate financial ratios and the importance of comparing these ratios to industry benchmarks. It also emphasizes the need for regular communication with stakeholders and the importance of providing timely and accurate information.

The third part of the document discusses the importance of risk management in financial reporting. It highlights the various risks that can arise from financial reporting, including the risk of misstatement, the risk of fraud, and the risk of non-compliance. The document outlines the various methods used to identify and assess these risks and the importance of implementing effective risk management strategies. It also discusses the role of internal controls in mitigating these risks and the importance of regular monitoring and reporting.

The fourth part of the document discusses the importance of ethical considerations in financial reporting. It highlights the various ethical issues that can arise from financial reporting, including the risk of manipulation, the risk of bias, and the risk of conflict of interest. The document outlines the various methods used to identify and assess these ethical issues and the importance of implementing effective ethical frameworks. It also discusses the role of internal controls in mitigating these ethical issues and the importance of regular monitoring and reporting.

The fifth part of the document discusses the importance of continuous improvement in financial reporting. It highlights the need for regular evaluation and improvement of the financial reporting process. The document outlines the various methods used to identify areas for improvement and the importance of implementing effective improvement strategies. It also discusses the role of internal controls in supporting continuous improvement and the importance of regular monitoring and reporting.

were plotted, as in Fig. 4, for the case in which a single item was presented as the critical element and a display containing several items was presented as the field to be scanned. When plotted in this manner, it cannot be conclusively argued that either a self-terminating or an exhaustive serial model can handle their results.

The present data seem to be explained well by a serial-exhaustive scanning model. To obtain the theoretical predictions for this model, the lines of best fit were found for both release latencies and terminal latencies for the data in Fig. 4 by simultaneously minimizing the squared deviations for positive and negative responses. The obtained slopes were 19.1 for release data and 25.0 for response data; the intercepts were 324 for positive release data, 348 for negative, 444 for positive terminal data, and 474 for negative. The fit of these theoretical lines to the data is shown in Fig. 5. Except for the negative terminal latency data, the fit seems to be exceptionally good. Figure 5 also presents the theoretical serial position curves; the discrepancy between theory and data here is due mainly to the fact that for the three largest display sizes, Ss responded substantially faster when the critical element was the first letter on the left than when it was in any other position. It is possible that when a match is detected in the first position, Ss have a slight tendency to terminate their scan before processing the whole display.

The fact that the slope for the terminal response data is significantly greater than the slope for the release data indicates that the release time may not be a valid measure of the termination of the scanning process. The difference in slopes of 5.9 msec. may be due to a premature

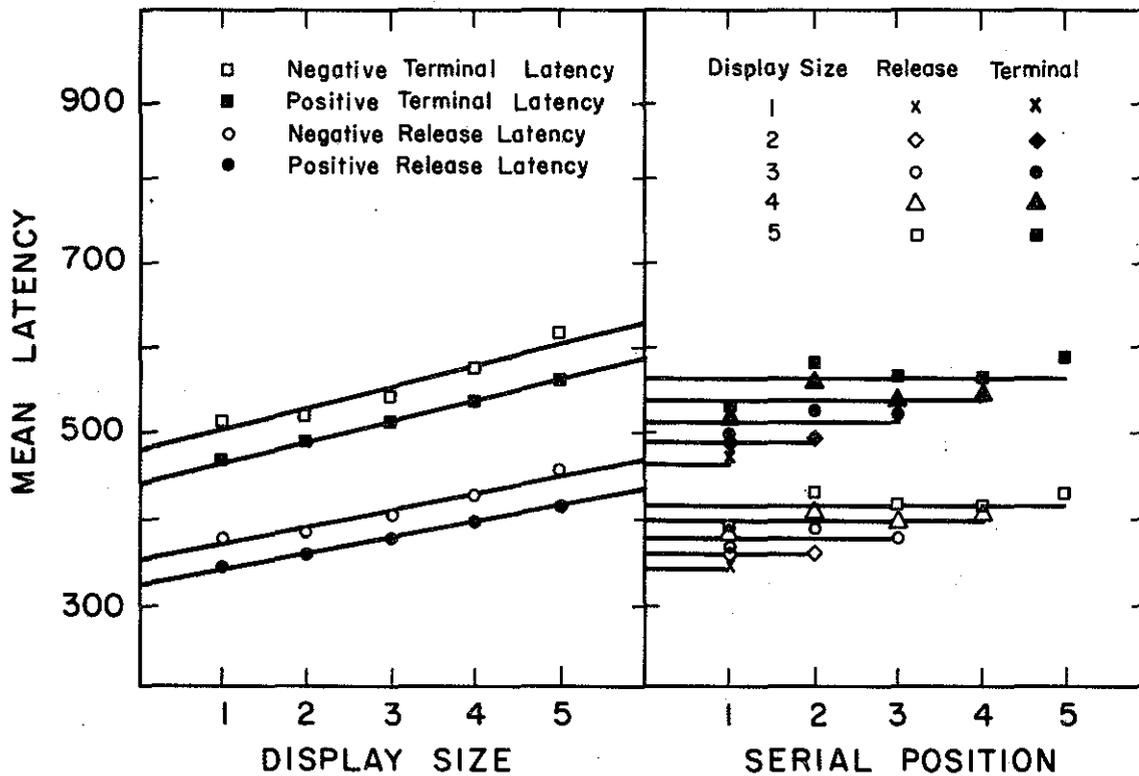


Fig. 5. Latency of positive and negative responses as a function of display size (left panel) and latency of positive responses as a function of the serial position of the critical element (right panel) averaged over all S_s . The solid lines represent the values predicted by the serial-exhaustive scanning model.

release for larger display sizes, with S deciding which response to make after initiating the release response.

There are some differences between Groups 1 and 2 in the present study, particularly in the slopes of the best-fitting lines. This result may be interpreted in terms of findings from a previous study (unpublished) in which response keys were located to the left and right of the center key as S faced the screen. In this case, as display size increased, both release and terminal latencies increased at a relatively faster rate if the positive key was located to the right rather than to the left of the center key. The Ss for whom the positive key was on the right reported that they felt they were scanning from left to right and that the position of the response keys was incompatible with this type of scan; i.e., it seemed to be difficult to scan through the list to the right side of the display and, having not detected the critical element, initiate a left response. In the present study, while not having eliminated the effects of possible response incompatibility, the differences between the two groups are much less.

In the previous study, the exposure time for the display was considerably less than in the present study (i.e., 150 msec. versus 400 msec.). Figure 6 presents release and terminal latencies for positive and negative responses as a function of display size, averaged over the eight Ss in that study. Also shown are the average serial position curves. Slight qualitative differences may be observed between the serial position curves shown in Fig. 6 and those obtained in the present study. These may be explained, in part, by the fact that central fixation points (above and below the center display letter) were used in the

1. The first part of the document is a letter from the author to the editor, dated 10/10/1964. The letter is addressed to the editor of the "Journal of the American Medical Association" and is signed by "Dr. J. H. [Name]". The letter discusses the author's interest in the journal and the possibility of contributing to it. The author mentions that he has been reading the journal for some time and has found it to be a valuable source of information. He expresses his hope that the journal will continue to be a leading publication in the field of medicine.

2. The second part of the document is a letter from the editor to the author, dated 10/15/1964. The letter is addressed to "Dr. J. H. [Name]" and is signed by "The Editor". The editor thanks the author for his letter and expresses his interest in the author's work. He mentions that the author's work has been reviewed by the editorial board and that they have decided to accept it for publication. The editor also mentions that the author's work will be published in the next issue of the journal.

3. The third part of the document is a letter from the author to the editor, dated 10/20/1964. The letter is addressed to the editor and is signed by "Dr. J. H. [Name]". The author thanks the editor for his letter and expresses his appreciation for the editor's interest in his work. He mentions that he is pleased to hear that his work has been accepted for publication and that he is looking forward to seeing it in the journal. The author also mentions that he will be submitting a second article to the journal in the near future.

4. The fourth part of the document is a letter from the editor to the author, dated 10/25/1964. The letter is addressed to "Dr. J. H. [Name]" and is signed by "The Editor". The editor thanks the author for his letter and expresses his appreciation for the author's work. He mentions that the author's work has been reviewed by the editorial board and that they have decided to accept it for publication. The editor also mentions that the author's work will be published in the next issue of the journal.

5. The fifth part of the document is a letter from the author to the editor, dated 10/30/1964. The letter is addressed to the editor and is signed by "Dr. J. H. [Name]". The author thanks the editor for his letter and expresses his appreciation for the editor's interest in his work. He mentions that he is pleased to hear that his work has been accepted for publication and that he is looking forward to seeing it in the journal. The author also mentions that he will be submitting a second article to the journal in the near future.

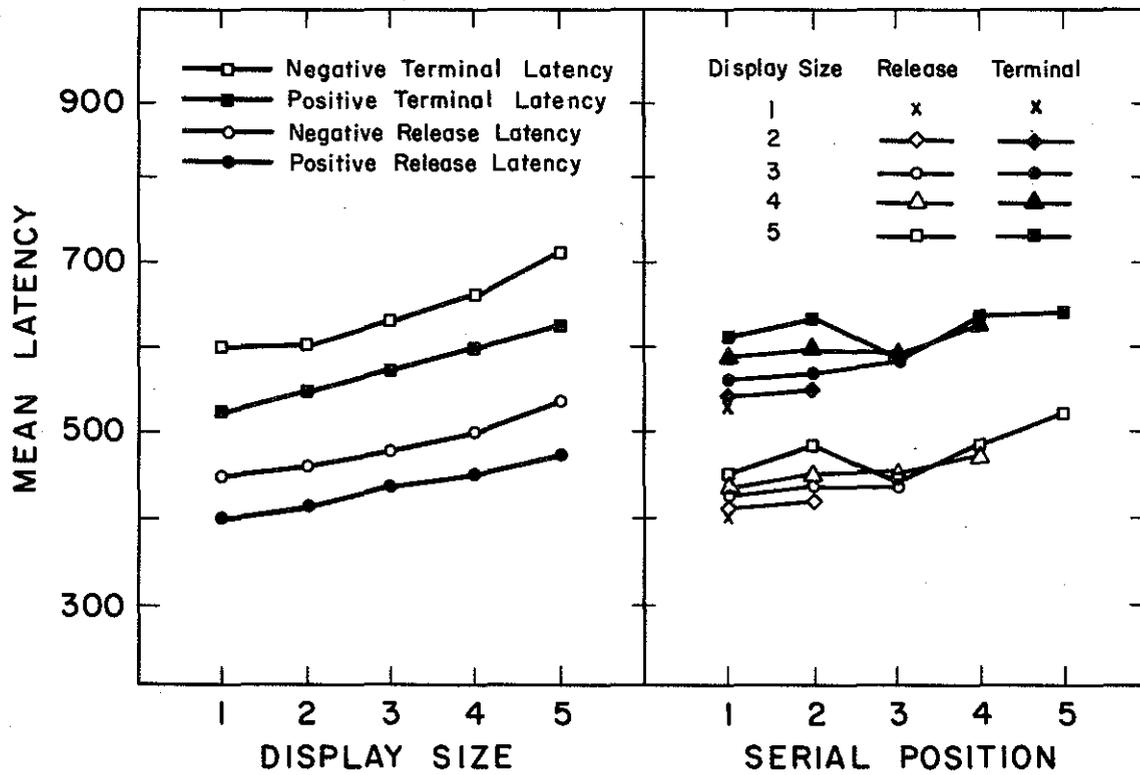


Fig. 6. Latency of positive and negative responses as a function of display size (left panel) and latency of positive responses as a function of the serial position of the critical element (right panel) averaged over eight Ss in a previous study.

previous study, but they were eliminated for the experiment reported here. No major qualitative differences were observed between the results of the two studies; the only differences being lower error rates (2.6% as compared with 1.6% in the present study) and faster latencies when using the longer exposure time. The slopes of the lines obtained in the two studies are remarkably similar (18.4 and 21.6 for positive and negative release latencies, and 24.5 and 28.6 for positive and negative terminal latencies, respectively, as compared with 18.3, 19.9, 23.8, and 26.2 obtained in the present study). Therefore, while the exposure time in this study was long enough to allow more than one fixation, it is unlikely that Ss were changing their fixation point before initiating a response.

While the serial exhaustive scanning model predicts the overall results of the present study, a parallel scanning model may also be used to make the same predictions. Sternberg (1966, 1967) has rejected a parallel scanning model because of the linear increase in latency with increasing display size. He argues that if items are processed independently and the processing time for each item has a non-zero variance, then for any parallel model there is an upper bound on the negative latency curve that falls below the best fitting linear function. However, if the independence requirement is relaxed, it can be shown that there are parallel models which make exactly the same predictions as the serial exhaustive model. As an example of such a parallel process, consider a model in which at any instant during S's scan, the processing time for each unprocessed item is exponentially distributed with a time constant $\lambda/(d-i)$ where d is the number of items in the display and i is the number of elements that have already completed processing. It can be shown that

in this case the mean time to process all items is d/λ . Thus if S does not respond until all items have been processed, both positive and negative response latencies will increase linearly with display size and the two lines will have the same slope. This can be viewed as a model in which S has a fixed amount λ of "processing energy" which is distributed over those items which have not yet been processed. It can be shown that the predictions presented above are independent of how the processing energy is distributed over the elements being processed at any point in time.

In conclusion, it is clear that a serial, self-terminating scanning model is inadequate to handle the results of the present study. Of course there is no question that in a task requiring multiple eye fixations, such as scanning a long list of items (Neisser, 1963), the search terminates with the processing of the target item. However, it is doubtful that models developed for these types of tasks are directly applicable to the processing of information available in briefly presented displays. The question of whether or not information obtained in a single eye fixation is processed exhaustively has not been decisively answered, despite the fact that an exhaustive serial scanning model predicts most of the data obtained here. Some value is seen in further investigation of parallel models for visual detection tasks in which the distinctions made between exhaustive and self-terminating versions of the process are not clearly evident, and indeed they may be identical if the processes are completely dependent. An experiment is currently in progress where the number of critical elements is varied within a fixed display size.

The effects of target redundancy on response latency should yield further insights into the nature of the scanning process, perhaps providing evidence for a more general processing model and deciding the issue of self-terminating versus exhaustive processing.

REFERENCES

- ESTES, W. K., & TAYLOR, H. A. A detection method and probabilistic models for assessing information processing from brief visual displays. *Proceedings of the National Academy of Sciences*, 1964, 52, No. 2, 446-454.
- ESTES, W. K., & TAYLOR, H. A. Visual detection in relation to display size and redundancy of critical elements. *Perception and Psychophysics*, 1966, 1, 9-16.
- ESTES, W. K., & WESSEL, D. L. Reaction time in relation to display size and correctness of response in forced-choice visual signal detection. *Perception and Psychophysics*, 1966, 1, 369-373.
- HOLMGREN, J. Visual search with imperfect recognition. *Perception and Psychophysics*, 1968, 4, 247-252.
- NEISSER, U. Decision time without reaction time: Experiments in visual scanning. *American Journal of Psychology*, 1963, 76, 376-385.
- NICKERSON, R. S. Response times with a memory-dependent decision task. *Journal of Experimental Psychology*, 1966, 72, 761-769.
- STERNBERG, S. High-speed scanning in human memory. *Science*, 1966, 153, 652-654.
- STERNBERG, S. Scanning a persisting visual image versus a memorized list. Paper presented at the annual meeting of the Eastern Psychological Association, 1967.

