Journal of Experimental Psychology
1972, Vol. 94, No. 1, 58–67

EVIDENCE OF BOTH PERCEPTUAL FILTERING AND RESPONSE SUPPRESSION FOR REJECTED MESSAGES IN SELECTIVE ATTENTION [1]

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In 10 replications of the same design ($N = 165$), *S*s rapidly named series of digits presented in a focal channel (visual for Replication I–VIII, auditory for Replication IX–X) while hearing simultaneous distracting digits (dichotic presentation in Replication IX–X). Rate of stimulus presentation was varied in the range from 1 trial/1 sec to 1 trial/4 sec. In 5 of the 10 replications, mostly those using the slower stimulus presentation rates, conflict due to distractors was reduced when the same digit was repeated for several trials in the distractor channel. Of these 5 replications, evidence for both perceptual filtering prior to verbal analysis of distractor content and suppression of responses to the distractor was obtained in 4. These and other results indicated that the nervous system may (*a*) limit perceptual analysis of verbal distractor sequences that are either random or predictable and (*b*) suppress verbal responses that tend to be elicited by predictable distractors. These perceptual-filtering and response-suppression processes apparently function best at relatively slow stimulus input rates.

In 1953, Colin Cherry described a novel technique for demonstrating the capacity of humans to attend selectively to one of two simultaneous verbal messages. Cherry required his *S*s to repeat, verbatim, the selected (or primary) message as it was being received. This "shadowing" task was relatively easy when the primary and secondary messages differed from each other in basic physical features, such as spatial location or pitch. On the basis of these results and others, Broadbent (1958) proposed that selective attention was accomplished by a perceptual-filtering mechanism that acted on the basis of elementary analysis of physical properties of messages. The hypothetical filter functioned to prevent further perceptual analysis at verbal levels for any messages other than those marked by the physical features of the primary message. This filter is shown schematically in Fig. 1.

Subsequent research, much of it by Treisman (1964), indicated that important information in the secondary message was at least partly analyzed verbally. The evidence for this took the form of findings that shadowing of the primary message could be disrupted if permanently important stimuli, such as one's name, or temporarily important ones, such as a word that fit into the context of the primary message, appeared in the secondary message. Treisman accordingly modified Broadbent's (1958) filter conception, declaring that the filter did not totally prevent verbal analysis of rejected messages but, rather, attenuated the rejected message's signal properties to the point that only important stimuli could receive full verbal analysis. An alternative conception of the selection process was proposed by Deutsch and Deutsch (1963) and, more recently, restated by Norman (1968). In this alter-

[1] This research was partially supported by Grants GS-1601 and GS-3050 from the National Science Foundation and by Grant 1-R01-MH20527-01 from United States Public Health Service. A paper with the same title, read by the author at the meetings of the Psychonomic Society in San Antonio, Texas, November 1970, reported preliminary analyses of Replications I–VI. The author wishes to thank Peter D. Jay and Douglas B. Henderson for their assistance in conducting the study, David D. S. Poor for extensive assistance with data analysis, and Harvey G. Shulman for critical reading of an earlier draft of this report. Analyses were performed using the REACT Program written by David D. S. Poor and Thomas Crunkilton to reduce the data prior to significance tests using MANOVA (Clyde, 1969).

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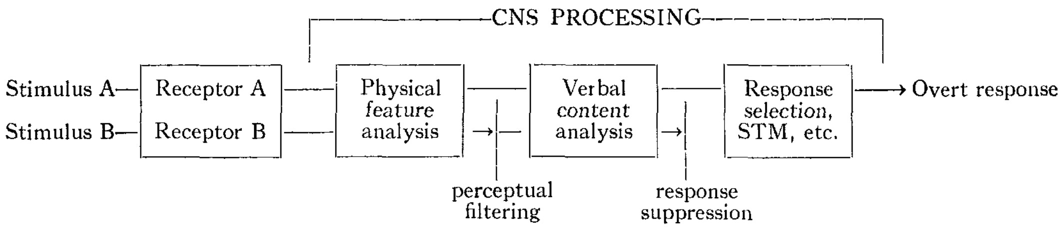

FIG. 1. Perceptual filtering and response suppression hypotheses.

native conception, it is assumed that all rejected messages are analyzed to the point of verbal recognition. Selective attention is assumed to be achieved by limitation of postperceptual processes such as holding message content in short-term memory storage or selection of an overt response. This "response-suppression" hypothesis is schematized by the dashed vertical line placed after the block labeled "verbal content analysis" in Fig. 1. Unfortunately, the shadowing task, as used in selective listening experiments, has not been fully satisfactory in discriminating between the perceptual-filtering and response-suppression hypotheses (discussions of the limitations of the shadowing task have been provided by Greenwald, 1970b, pp. 50–52, and Norman, 1969, pp. 19–22).

The present research took advantage of an experimental situation in which secondary-message rejection is known to be difficult (Greenwald, 1970a, 1970b). In this task, *S* is required to name, as rapidly as possible, visually presented digits that are sometimes accompanied by simultaneous auditorily presented conflicting digits and sometimes by a simultaneous auditory tap. The difficulty in rejecting the secondary message is shown by slower reaction times to the visual stimuli accompanied by conflicting auditory digits than to those accompanied by taps. In Greenwald's (1970b) experiment these reaction time differences ranged from 29.5 msec., with an 8-sec. trial presentation rate, to 44.0 msec., with a 1-sec. rate.

The idea for the present series of experiments was to attempt to eliminate the conflict effect of Greenwald's (1970a, 1970b) experiments by habituation—that is, by repeating a conflicting auditory digit stimulus for several trials. If this device can eliminate the conflict effect, it should then be possible to interrupt the habituation process to determine whether conflict was eliminated because of perceptual filtering or response suppression. In order to use the habituation procedure to test hypotheses about selective attention processes, it was necessary to make some assumptions about how these processes would become manifest in the reaction time data. These assumptions will be noted where appropriate, and a résumé of them is provided in the Discussion section.

METHOD

Apparatus.—Simultaneous visual and auditory digit stimuli were recorded and played back for *S* on videotape recording equipment. The distracting auditory stimuli were digits spoken in a male voice. Visual digit stimuli were produced by an Industrial Electronics Engineers Series 10 one-plane readout. The auditory digit stimuli, in sequences and at intervals as described below, were first recorded on audiotape. This audiotape was then used with voice-operated circuitry to control visual digit onsets while both types of stimuli were being recorded on videotape. Simultaneity of auditory and visual stimulus onsets was achieved with the aid of some accessory timing equipment as described by Greenwald (1970a, p. 393). As played to *S*s on a small screen monitor, digits were 5 cm. high and were viewed at eye level from about 50 cm. The monitor was mounted behind a panel resting on top of the table at which *S* was seated. Distracting auditory digits were heard at about 85 db. The *S* gave spoken digit responses into a hand-held microphone. Reaction times were automatically recorded with the aid of two voice-operated circuits, the first activated by the auditory stimulus on videotape to start a millisecond counter, the second activated by *S*'s response to terminate the counter.

Subjects.—Volunteers were recruited through an advertisement offering base pay of $1.25 for a 1-hr. session plus the possibility of performance bonuses up to another $1.25 per session. All respondents to the advertisement, male and female, were used for the experiment unless they had difficulty with English or were victims of apparatus failures.

Overview of procedure.—An experimental session consisted usually of 10 blocks of trials, averaging 85 trials each in length. Each trial involved presentation of a visual digit stimulus that was to be named rapidly by *S*, accompanied by a simultaneous auditory distractor that *S* was instructed to ignore. The distractor was most often a conflicting digit, but was sometimes a nonconflicting digit and sometimes an equally loud tap, as called for by the design. Blocks of trials were constructed by stringing together seven subseries of trials, the lengths of which varied randomly among the values of 10, 13, or 16 trials. Each subseries consisted of a variable length of *habituation trials*, during which the same auditory distractor was repeated, ended by two *critical trials*. Hypotheses were tested with reaction times from critical trials, reaction times not being analyzed for the preceding habituation trials (although *S*s believed that all trials were equally important). In order to simplify presentation, description of the specific stimulus sequences used for the various types of subseries is deferred to the Results section. Trial presentation rates were constant within sessions, but were varied in the range from 1 every second to 1 every 4 sec., in order to assess the sensitivity to input rates of the selective attention processes being observed. Blocks of trials were separated by 30-sec. rests.

Replications I–III.—These three replications of the basic procedure differed only in trial presentation rates with 30 *S*s at each of three rates, 1, 2, or 4 sec. Replication III, at the 4-sec. rate, employed only five blocks of trials in order to keep the length of the experimental session reasonable. All digit stimuli were selected from the set 1, 2, 4, 6, 8, and 9, these six digits having been employed because they were monosyllabic and commenced with mutually distinct phonemes.

Replications IV–VI.—These three corresponded exactly to Replications I–III, with the exception that a single group of 30 *S*s served for all three, in separate sessions conducted within the space of a week and with order of replications counterbalanced across *S*s.

Replications VII–VIII.—The set of stimulus digits, both for the primary visual stimuli and the auditory distractors, was changed to 1, 2, 3, 4, 5, and 6. Twenty-one *S*s served in two sessions at 1-sec. (Replication VII) and 3-sec. (Replication VIII) trial rates with order of replications counterbalanced.

Replications IX–X.—For these, *S*'s task was changed to naming digits presented auditorily to one ear while distracting digits were presented simultaneously to the other. The stimulus materials were prepared by first recording, on Track 1 of a stereo audio recorder, the sequences of primary stimuli in a female voice. These stimulus sequences were identical to the sequences of visual stimuli used in Replication VII–VIII. The distracting stimuli, identical to the auditory distractors of Replication VII–VIII, were recorded in the same male voice used to record the distracting auditory stimuli for all previous replications. The technique for recording the distractors was less than ideal, in that the male and female voice onsets varied randomly up to about 150 msec. from being exactly coincidental, although the average coincidence was much better than this. A superior method would have been computer synchronization (e.g., Treisman & Riley, 1969), but available facilities did not permit this. In recording reaction times for these replications, the millisecond counter was always started by the primary stimulus in the female voice so that the recording of reaction times would not be contaminated by the voice asynchronies. Twenty-four *S*s were distributed among the four cells of a 2 × 2 factorial design, varying ear to which the primary stimulus was presented and order of sessions at the 1-sec. (Replication IX) and 3-sec. (Replication X) trial presentation rates.

Results

Errors.—In general, error rates were low and did not provide a basis for testing hypotheses. Errors averaged under 2% overall, with all *S*s under 10%, and only 5 out of 165 *S*s exceeding 5%.

The conflict effect.—Table 1 gives the stimulus sequences used to assess the conflict effect that was expected on the basis of earlier research (Greenwald, 1970a, 1970b) and gives estimates of the magnitude of this effect for the 10 replications. Conflict was measured by the difference in reaction times between trials on which the auditory distractor did (B2) or did not (A2) conflict with the correct response.[3] Trials A2 and B2 followed series of taps in the distractor channel on the assumption that this would prevent *S*s from having selective attention processes in effect when these trials occurred. The obtained conflict effect, significantly greater than zero in 7 of the 10 replications, indicated that this assumption was justified. On the right of Table 1 it may be seen that conflict effects tended to be obtained most reliably at the 3-sec. and 4-sec. trial presentation rates.

Effect of change in the distractor channel.—An effect unrelated to perceptual-filtering or response-suppression processes was observed in the comparison of Trials A1 and

[3] A2 refers to the second critical trial in sequences of Type A; B2 to the second critical trial in sequences of Type B; etc.

TABLE 1

TEST OF THE CONFLICT EFFECT

Stimulus sequences	Stimuli: Habituation trials							Critical trials[a] 1	Critical trials[a] 2	Replication	Estimate[b] (in msec.)
Focal stimuli	**2**	**4**	**9**	. . .	**6**	**6**	**2**	**9**	**8**		
										1-sec. rate	
										I	13*
										IV	1
										VII	10
										IX	35**
										2-sec. rate	
										II	26**
										V	7
Distractors Type A	*Tap*	*Tap*	*Tap*	. . .	*Tap*	*Tap*	*Tap*	*Tap* (399)	*8* (415)		
										3-sec. rate	
										VIII	22**
										X	57**
Type B	*Tap*	*Tap*	*Tap*		*Tap*	*Tap*	*Tap*	*Tap* (399)	*2* (440)		
										4-sec. rate	
										III	42**
										VI	38**

Note.—The correct response on each trial was to name the focal stimulus (boldface). Stimuli for correct responses were provided visually in Replication I–VIII, auditorily in IX and X. Mean reaction times in milliseconds for correct responses are given in parentheses, unweighted over the 10 replications. Stimulus distractors were always auditory (dichotic presentation in Replication IX and X).

[a] Each type of critical trial was experienced between 5 and 10 times by each *S* in each replication.

[b] Estimates of the conflict effect were computed for each replication by the formula, B2–A2. (A2 = second critical trial in sequences with distractors of type A, etc.)

* Greater than zero, $p < .01$, two-tailed.

** Greater than zero, $p < .001$, two-tailed.

A2 (see Table 1). Reaction times for Trial A2 were slower than those for A1 by an amount ranging from 5 to 34 msec. over the 10 replications, this difference being reliably greater than zero ($p < .01$) in 6 replications. Since the distractor on Trial A2 never conflicted with the correct response, it may be concluded that stimulus change per se in the secondary channel was an effective distractor.

Habituation of the conflict effect.—Table 2 presents the sequences used to determine if the conflict effect was successfully habituated by the device of repeating a single distractor over a series of trials. In the absence of habituation, it was expected that reaction times for Trial C1 (see Table 2) should exceed those for A1 or B1 by the amount of the conflict effect. Accordingly, habituation was measured by the formula [(B2 − A2) − (C1 − A1)]. This difference was significantly greater than zero in five of the seven replications for which a conflict effect was found, as shown in Table 2. An attempt will be made in the Discussion section to suggest why conflict and habituation were more likely to be found in some replications than in others. For the present, tests of selective attention hypotheses will be described only for those replications in which the significant habituation effect indicated that attention selectivity was occurring.

Tests of the response-suppression hypothesis.—The sequences used to determine if response suppression was occurring as a component of selective attention are shown in Table 3, together with data from the five replications in which attention selectivity was observed (i.e., in which there was significant habituation of a conflict effect). The only difference between Sequences C and D was that the distractor repeated during habituation trials was different from the correct response required on Trial C2, but was the same as the correct response on Trial D2. If *S* has achieved attention selectivity by suppres-

TABLE 2

Test of Habituation of the Conflict Effect (Data Only for Seven Replications with Significant Conflict Effects)

Stimulus sequences	Stimuli: Habituation trials							Critical trials 1	Critical trials 2	Replication	Estimate[a] (in msec.)
Focal stimuli	**2**	**4**	**9**	. . .	**6**	**6**	**2**	**9**	**8**		
										1-sec. rate	
										I	−11
										IX	30*
										2-sec. rate	
										II	26***
Distractors											
Type A	*Tap*	*Tap*	*Tap*	. . .	*Tap*	*Tap*	*Tap*	*Tap* (387)	*8* (405)	3-sec. rate	
										VIII	0
Type B	*Tap*	*Tap*	*Tap*	. . .	*Tap*	*Tap*	*Tap*	*Tap* (387)	*2* (438)	X	47**
Type C	*1*	*1*	*1*	. . .	*1*	*1*	*1*	*1* (397)	. . .	4-sec. rate	
										III	38***
										VI	29***

Note.—The correct response on each trial was to name the focal stimulus (boldface). Mean reaction times in milliseconds for correct responses are given in parentheses, unweighted over the seven replications showing significant conflict effects.

[a] Estimates of the habituation effect were computed for each replication by the formula, [(B2–A2)–(C1–A1)]. (A1 = first critical trial in sequences with distractors of type A, etc.)

* Greater than zero, $p < .05$, two-tailed.

** Greater than zero, $p < .01$, two-tailed.

*** Greater than zero, $p < .001$, two-tailed.

sing the response of naming the distractor stimulus, then the reaction time for Trial D2 should be greater than that for Trial C2. This test assumes that if a response is suppressed on a series of habituation trials, it will continue to be suppressed on a following trial on which a novel distractor occurs (e.g., Trial D2). The significant

TABLE 3

First Test of Response-Suppression Component of Selective Attention (Data Only for Five Replications with Significant Habituation Effects)

Stimulus sequences	Stimuli: Habituation trials							Critical trials 1	Critical trials 2	Replication	Estimate[a] (in msec.)
Focal stimuli	**2**	**4**	**9**	. . .	**6**	**6**	**2**	**9**	**8**		
										1-sec. rate	
										IX	1
										2-sec. rate	
										II	18**
Distractors											
Type C	*1*	*1*	*1*	. . .	*1*	*1*	*1*	*1* (377)	*2* (396)	3-sec. rate	
										X	28*
Type D	*8*	*8*	*8*	. . .	*8*	*8*	*8*	*8* (377)	*2* (415)	4-sec. rate	
										III	26**
										VI	21**

Note.—The correct response on each trial was to name the focal stimulus (boldface). Mean reaction times in milliseconds for correct responses are given in parentheses, unweighted average over the five replications for which the habituation effect was significant.

[a] Estimates of the response-suppression component of the habituation effect were computed for each replication by the formula, (D2 − C2). (D2 = second critical trial in sequences with distractors of Type D.)

* Greater than zero, $p < .01$, two-tailed.

** Greater than zero, $p < .001$, two-tailed.

TABLE 4

SECOND TEST OF THE RESPONSE-SUPPRESSION COMPONENT OF SELECTIVE ATTENTION (DATA ONLY FOR FIVE REPLICATIONS WITH SIGNIFICANT HABITUATION EFFECTS)

Stimulus sequences	Stimuli: Habituation trials							Stimuli: Critical trials 1	Stimuli: Critical trials 2	Replication	Estimate[a] (in msec.)
Focal stimuli	**2**	**4**	**9**	. . .	**6**	**6**	**2**	**9**	**8**		
										1-sec. rate IX	2
										2-sec. rate II	13*
Distractors											
Type E	*8*	*8*	*8*	. . .	*8*	*8*	*8*	*8* (377)	*8* (377)	3-sec. rate X	−6
Type G	*1*	*6*	*8*	. . .	*2*	*9*	*4*	*1* (393)	*8* (375)	4-sec. rate III	6
										VI	−9

Note.—The correct response on each trial was to name the focal stimulus (boldface). Mean reaction times in milliseconds for correct responses are given in parentheses, unweighted average over the five replications for which the habituation effect was significant.

[a] Estimates of the response-suppression component of the habituation effect were computed for each replication by the formula, (E2 − G2). (E2 = second critical trial in sequences with distractors of Type E.)

* Greater than zero, $p < .01$, two-tailed.

difference obtained in four out of five replications for the (D2 − C2) contrast indicates both that this assumption was correct and that response suppression was a component of the selective process induced by the habituation procedure.

A second test of the response-suppression effect was based on reasoning similar to that used for the first test, using a comparison of Trial E2 with Trial G2 (see Table 4). Both of these trials were nonconflict trials; they differed in that Trial E2 was preceded by repeated distractors that anticipated its correct response, while Trial G2 was preceded by a random series of distractors that should not permit response suppression. The response-suppression effect (E2 − G2) was manifest only in one of the five replications in which demonstrable attention selectivity was found. There is no ready explanation for the contrast between the strong confirmation of response suppression obtained in the Table 3 data and the much weaker results of Table 4. Presumably the assumptions used to generate the Table 4 test were, in some as yet unknown manner, in error.

Tests of the perceptual-filtering component of selective attention.—Testing the possibility that perceptual filtering was a component of selective attention required obtaining data from the four different types of distractor sequences shown in Table 5. Trials A2 and F2 were both nonconflict trials, while B2 and C2 were both conflict trials. The sequences differed in that F2 and C2 were preceded by repetition of a constant distracting digit, while A2 and B2 were not. It was reasoned that if the conflict effect measured by (C2 − F2) was smaller than that measured by (B2 − A2), it must be because the repeated digit distractors had the consequence of reducing perceptual analysis of the distracting auditory channel.[4] Evidence for such perceptual filtering was obtained at a statistically significant level in three of the five replications examined.

A second finding indicative of perceptual filtering was obtained unexpectedly. Re-

[4] Logically there is another possibility. The *S* may be fully analyzing the verbal content of the distractor on each trial and, simultaneously, suppressing any response to it. While this is a logical possibility—one that corresponds, in fact, to the form of the response-suppression hypothesis suggested by Deutsch and Deutsch (1963)—it is not compatible with the data presented in Table 3 for Trial D2. The effect on Trial D2 indicated that response suppression was operating on the basis of anticipated, rather than current, content of the distractor channel.

TABLE 5

FIRST TEST OF PERCEPTUAL-FILTERING COMPONENT OF SELECTIVE ATTENTION (DATA ONLY FOR FIVE REPLICATIONS WITH SIGNIFICANT HABITUATION EFFECTS)

Stimulus sequences	Stimuli									Replication	Estimate[a] (in msec.)
	Habituation trials							Critical trials			
								1	2		
Focal stimuli	**2**	**4**	**9**	· · ·	**6**	**6**	**2**	**9**	**8**	1-sec. rate	
										IX	11[b]
										2-sec. rate	
										II	18**
Distractors											
Type A	*Tap*	*Tap*	*Tap*	· · ·	*Tap*	*Tap*	*Tap*	*Tap* (371)	*8* (387)		
										3-sec. rate	
Type B	*Tap*	*Tap*	*Tap*	· · ·	*Tap*	*Tap*	*Tap*	*Tap* (371)	*2* (427)	X	36**[b]
Type F	*1*	*1*	*1*	· · ·	*1*	*1*	*1*	*1* (377)	*8* (375)	4-sec. rate	
Type C	*1*	*1*	*1*	· · ·	*1*	*1*	*1*	*1* (377)	*2* (396)	III	24*
										VI	7

Note.—The correct response on each trial was to name the focal stimulus (boldface). Mean reaction times in milliseconds for correct responses are given in parentheses, unweighted average over the five replications for which the habituation effect was significant.

[a] Estimates of the perceptual-filtering component of the habituation effect were computed for each replication by the formula [(B2 − A2) − (C2 − F2)]. (B2 = second critical trial in sequences with distractors Type B.)

[b] Critical trials of Type F2 were, through an oversight, not included in the design of Replication VII–X. Because the relation between reaction speed on Trials F1 and F2 was observed to be quite reliable in Replication I–VI, estimates were made for the missing Trial F2 on the basis of that relationship. These estimates were used to compute the values that are footnoted.

* Greater than zero, $p < .05$, two-tailed.

** Greater than zero, $p < .01$, two-tailed.

call the earlier evidence that stimulus change per se in the distractor channel—that is, change from taps to a nonconflicting digit—slowed reaction time (compare Trials A1 and A2 in Table 5). Notice, however, that the change to a nonconflicting distractor on Trial F2 did not produce a similar slowing. This suggests that the change of distractor stimulus from F1 to F2 was less noticeable for *S*s than

TABLE 6

SECOND TEST OF PERCEPTUAL FILTERING, USING RANDOM SERIES OF DISTRACTORS

Stimulus sequences	Stimuli									Replication	Estimate[a] (in msec.)
	Habituation trials							Critical trials			
								1	2		
Focal stimuli	**2**	**4**	**9**	· · ·	**6**	**6**	**2**	**9**	**8**	1-sec. rate	
										IX	11
										2-sec. rate	
Distractors											
Type A	*Tap*	*Tap*	*Tap*	· · ·	· · ·	*Tap*	*Tap*	*Tap* (371)	*8* (387)	II	15*
										3-sec. rate	
Type B	*Tap*	*Tap*	*Tap*	· · ·	*Tap*	*Tap*	*Tap*	*Tap* (371)	*2* (427)	X	25
										4-sec. rate	
Type G	*1*	6	8	· · ·	2	9	4	*1* (393)	*8* (375)	III	32*
										IV	27*

Note.—The correct response on each trial was to name the focal stimulus (boldface). Mean reaction times in milliseconds for correct responses are given in parentheses, unweighted average over the five replications for which the habituation effect was significant.

[a] Estimates of the perceptual-filtering component of the habituation effect were computed for each replication by the formula [(B2 − A2) − (G1 − G2)]. (B2 = second critical trial in sequences with distractors Type B.)

* Greater than zero, $p < .01$, two-tailed.

was the change from A1 to A2. This would be consistent with the hypothesis that the repeated digit distractors had the effect of reducing perceptual analysis of the distractor channel.

A third demonstration of perceptual filtering was obtained from the sequences shown in Table 6. Distractor sequences of Type G differed from others in not involving repetition of a constant stimulus; rather the distractors were a random digit series, different from the random digits that were correct responses. It was expected that the conflict effect measured by the difference (G2 − G1) would equal the conflict effect measured by the (B2 − A2) difference. Contrary to expectation, the former conflict effect was substantially smaller than the latter, significantly so in 3 of the 5 replications in which attention selectivity was demonstrated. Evidently *S*s were capable of some limited attention selectivity when random distractor sequences were used. Since (*a*) there was no way that *S* could predict the distractor on Trial G1 for the purpose of suppressing the response to it, and (*b*) suppression of the response tendency to name an unpredictable distractor in the present task seems implausible (see Footnote 4), it must be concluded that this selectivity involved perceptual filtering (i.e., limitation of verbal analysis).

Discussion

Simultaneous perceptual filtering and response suppression?—The results for tests of perceptual filtering and response suppression indicated that both processes participated in the attention selectivity induced by the habituation procedure. If perceptual filtering prior to verbal analysis is occurring, why should response suppression also occur? Perhaps more important: How can the nervous system "know" what response to suppress if verbal analysis of distractor input has been restricted? This combination of processes is not necessarily paradoxical if it is assumed that the content of the distractor channel is fully verbally analyzed only for the first few trials of each habituation series. Once this much analysis has occurred, the nervous system (*a*) initiates a suppression of the response to the anticipated (continued) content of the distractor channel, and (*b*) reduces (or as Treisman (1964) has put it, attenuates) the level of perceptual analysis on the distractor channel. Such a multiprocess selective attention mechanism could be quite efficient and functional.

Summary of assumptions made in testing hypotheses.—The experimental design used to test hypotheses about selective attention processes would have been powerless without the following three built-in assumptions.

1. Selective processes induced by a habituation (distractor-repetition) procedure should carry over to the first trial on which the distractor stimulus is changed. This assumption was evidently valid; had it been invalid, it should not have been possible to reject null hypotheses on most of the present tests for response suppression and perceptual filtering.

2. Suppression of the response tendency to name a distractor stimulus operates only on the basis of anticipated content of the distractor channel, not on the basis of current content. Distinctions between perceptual filtering and response suppression would have been impossible without this assumption, which has already been mentioned (Footnote 4). The validity of this assumption can be argued on the basis of finding reliable conflict effects (approximately 20 msec.) on trials of Types D2 (see Table 3) and G1 (see Table 6), for which distractor content was not anticipatable. Had it been possible for *S*s to suppress responding on the basis of current distractor content alone, conflict effects on these trials should have been virtually nonexistent. Note that conflict effects *were* virtually nonexistent on trials of Type C1 (see Table 5), for which the content of the distractor channel was predictable.

3. Effects are additive. The assumption that multiple determinants of reaction times on specific types of critical trials would act additively has remained hidden to this point. This assumption was essential to some of the hypothesis tests. Among the effects that enter into the assumed additive model (in different combinations on different types of critical trials) are (*a*) a "base" reaction time, including all the component processes involved in the basic task of naming the digit in the focal channel, (*b*) a conflict effect, (*c*) an effect of habituation due to distractor repetition, (*d*) an effect due to change per se in the distractor channel, (*e*) an effect of suppressing the response tendency to name an anticipated

distractor digit, and (*f*) an effect of limiting verbal analysis when the distractor channel content is either randomly verbal or predictably verbal. When rejections of null hypotheses rested on the comparison of two types of critical trials assumed to differ in the presence or absence of only one of these components, the assumption of additivity was nonessential. However, the test of the habituation effect (Table 2) and the two tests of the perceptual-filtering effect (Tables 5 and 6) required comparison of more than two types of critical trials. The possibility of nonadditivity as an alternative interpretation for the perceptual-filtering effects observed cannot be ruled out; the perceptual-filtering-interpretation acquires some plausibility, however, from its being supported by two tests (Tables 5 and 6) involving different sets of assumed additive components.

Potentially more important than the possibility of nonadditivity causing artifactual rejection of null hypotheses is the possibility of its producing artifactual failures to reject null hypotheses. Such may have occurred in the failures to find habituation and conflict effects in some of the replications, and in the failure of the second test of the response-suppression hypothesis. Also worthy of consideration is the possibility that the specification of assumed multiple determinants of reaction times on various types of critical trials may have been incomplete.

Selective attention as a function of signal rate.—A study that was preliminary to the one reported here (Greenwald, 1970b) found conflict effects to decrease with slowing of trial presentation rates, indicating superior attention selectivity with slower input rates. In the present study, conflict effects were unexpectedly *smaller* with 1-sec. and 2-sec. rates than with the slower 3-sec. and 4-sec. rates. This discrepancy is undoubtedly due to procedural changes—habituation procedures were never used in the earlier study and trial blocks were much longer in the present study. The overall slowness of reaction times in the present replications employing 1-sec. and 2-sec. rates (relative to those using slower rates) was also unexpected and was contrary to the general rule that reaction times increase with increasing foreperiod length (e.g., Woodworth & Schlosberg, 1954, pp. 28–30). It may be hypothesized that, at the 1-sec. and 2-sec. rates, auditory feedback from *S*'s response on one trial may have been a distractor (above and beyond what *S* heard through the headset) that interfered with the response required for the next trial. This would suggest that the finding of only weak conflict effects for the six replications at the 1-sec. and 2-sec. rates may have been due to the fact that conflict in those replications was not confined to the trials on which it was expected to occur! With this reasoning, the present findings can be regarded as consistent with the author's earlier finding that attention selectivity flourished at relatively slow signal input rates.

Restrictions on generality of conclusions.—In considering the generalizability of the present demonstrations of perceptual filtering and response suppression, it is important to recognize those respects in which the present experimental task was unique. First, the task was one in which focusing attention may have been more difficult than in a number of other tasks used to study selectivity. The potency of interference of the auditory distractors for the digit-naming task was due, presumably, to what the author has elsewhere labeled "ideomotor compatibility"—that is, an especially strong tendency of a stimulus to evoke a response when the stimulus closely resembles sensory feedback from the response (Greenwald, 1972). Testing hypotheses about selective attention would not have been possible without this strong conflict effect as a base line against which to measure selectivity processes. Second, the selective processes observed here were primarily (but not exclusively) ones induced by distractor repetition. Selectivity based upon this habituation procedure may or may not resemble selectivity achieved with other procedures. These unique aspects of the present research task certainly encourage caution in extrapolating conclusions. At the same time, however, it is essential to note that the opportunity to discriminate perceptual-filtering from response-suppression processes was crucially dependent on these idiosyncracies.

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(Received October 1, 1971)