COMMENTS ON "SELECTIVE ATTENTION: PERCEPTION OR RESPONSE?"

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We cannot understand why Treisman and Geffen (1967) think their experiment argues against our theory (Deutsch and Deutsch, 1963). Briefly, Treisman and Geffen ask subjects to repeat and tap to certain words in one message, played to one ear, and only tap to such words when they occur in another message played to the other ear. They find that subjects neglect the words to which they only have to tap. According to our theory, stimuli with a greater weighting of importance inhibit certain outputs (such as storage, motor response) of the structures processing stimuli with a lesser weighting of importance. Now it seems to be clear that Treisman and Geffen have by their instructions (to tap and repeat one set of words and only to tap to another set of words) produced a situation in which one set of stimuli is given a larger weighting of importance than the other. It is therefore not surprising on our theory that the less important set is almost disregarded. It is instructive here to consider Lawson's (1966) very similar experiment. In this experiment the signals to which the subject has to tap do not also have to be repeated if they occur in the message which is being shadowed. (These signals are non-verbal.) Lawson's results are almost the opposite of Treisman and Geffen's, as would be expected from our theory. Treisman and Geffen have some difficulty in explaining the discrepancy. "It seems that analysis of simple physical signals precedes both the selective filter and the analysis of verbal content in the perceptual sequence, that the bottle-neck in attention arises chiefly in speech recognition where of course the information load is usually much higher. To confirm the belief that the verbal content of the secondary message was not being analysed, we find no evidence whatever of interference from secondary target words when these received no tapping response." (We quote the last sentence as just one example of the fact that Treisman and Geffen have failed to understand our theory. It is one of the major points of this theory to explain why "secondary" messages do not cause interference with the "primary" message while they are being analysed.) To return now to the subject of Lawson's experiments, we would suggest that the outcome of such experiments would be the same if instead of signals, words were used in Lawson's paradigm. These words should occur on both channels and should be distinguishable by another speaking voice. The subject should be asked to respond to, but not to repeat such words. To make sure the subject is not simply responding to differences in timbre, pitch, etc., the target words should be interspersed with other words. Treisman and Geffen could not then postulate differences in information load to explain an unfavourable result.

Finally we would like to make a comment on Treisman's own suggested amendment of Broadbent's theory. "If the filter reduced the signal-to-noise ratio of unattended messages rather than blocking them completely, words which were highly important or relevant to the subject might still be perceived despite this attenuation, provided that the criteria for detecting them were sufficiently low. This would have the biological advantage that the unattended messages could be monitored for any important signals without at the same time much increasing the load on the limited capacity available for speech recognition." (Treisman and Geffen, 1967). It would seem to us that Treisman's suggestion of attenuation would have quite the opposite effect. It seems evident that on the whole, a signal-recognizing (as distinct from signal-transmitting) system would be much more disrupted or taxed by having to recognize signals which were incomplete or noisy, than if such signals were clear. The "load" would clearly be increased over the case where no attenuation occurred. Similarly, a signal recognizing system would have to increase the amount of processing when it had to distinguish between signals some of which were incomplete or noisy. The introduction of corrupted messages could certainly never reduce the load on the system as compared with the case where such messages were not degraded. Such degradation would simply reduce the efficiency of decision made by a system. Treisman's proposed amendment to Broadbent's theory makes matters worse.

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A recent report by Treisman and Geffen (1967) suggests there is some ambiguity in the interpretation of a theory of attention proposed by Deutsch and Deutsch (1963). Perhaps one reader's view of the controversy might clarify some of the issues. The theory proposed by the Deutschs does not question the fact that the processing capacity of the nervous system is limited—after all it is a finite system; nor do they quarrel with the proposition that at some stage during the analysis of incoming messages there occurs a "single channel mechanism" which gives preferential treatment to some messages at the expense of others. Their theory is concerned with the question of where the single channel process arises. It is motivated by the consistent finding that complex stimuli, such as particularly important words, when they occur on a secondary channel supposedly being ignored do succeed in diverting a subject's attention from a primary task. They argue that these findings indicate the single channel process must occur after the messages have been fully analysed by the perceptual system and therefore impaired performance found under multitask conditions might be due to limitations in the storage of messages and responsiveness to them rather than their initial perceptual analysis. Since most tasks used to study attention involve a large memory component, there are no convincing grounds for attributing the observed decrements in performance to processes operating during the perception of the stimulus.

The main thrust of Treisman and Geffen's experiment appears to be that memory is not involved in their particular task and consequently decrements in performance cannot be associated with memory limitations. The point is debatable. On the average, several items intervene between the presentation of a target word and the subject's response. Interference effects on both messages often span a long string of items. These time periods cannot be accounted for in terms of simple reaction times and suggest that the storage of information is a necessary factor in the performance of Treisman and Geffen's experimental tasks.

Treisman and Geffen also show that, though the analysis is admittedly hazardous due to the small number of observations and the assumptions needed to determine the false alarm rate, the d′ statistic is lower for unshadowed messages than for shadowed messages. They imply that this difference in d′ indicates information is being lost during the perceptual analysis of the unshadowed material. While the reduction in d′ does indicate that information is being lost somewhere between the presentation of the signal and the subjects' response, it says nothing about where the loss occurs. It could be reasonably argued that

because of its relative unimportance, as emphasized by the instructions, the output of the perceptual analysis of the unshadowed message is only briefly and infrequently monitored perhaps at opportune times during the shadowed message. This would reduce the "hit rate" for target words in the unshadowed message. Since, according to the Deutschs' theory, performance on the dominant task prevents information in the secondary message from being transferred into a long-term storage, the subjects will often be faced with trying to decide whether a target word has occurred in the unshadowed message on the basis of a fast fading (STM) memory trace of the recently presented words. This would reduce the possible precision of discrimination and therefore measured detectability.

Treisman and Geffen point out the apparent contradiction of their results and the results of a study by Lawson (1966) who found no impairment when subjects monitored several non-verbal signals at the same time. The explanation offered seems to rely on an intuitive appeal to the relative processing capacity involved in the analysis of simple physical signals as opposed to that involved in the analysis of verbal messages. Processing capacity, however, is neither explicity defined or measured. Moreover it is probable that the information load on a processor is not simply related to the continuum of task "complexity." M. M. Taylor, S. M. Forbes, and I (1967) have found that even with standard psychophysical discrimination tasks such as the discrimination of the pitch or the intensity of a pure tone, the requirement of performing several such tasks at the same time substantially reduces the precision of discrimination for each task. Processing load may be related to the difficulty in discriminating between two signals rather than the complexity of the analytic operations assumed to be performed. These findings, however, again raise the question of the degree to which limitations in the storage of information would plausibly account for the impairment found with simple discrimination tasks.

Finally some clarification of the notion of attenuation would be useful. In particular it is not clear how the attenuation process affects the discrimination and identification of irrelevant messages. Simply attenuating a secondary message would not alter the signal to noise ratio and therefore the precision of discrimination would be unaffected. It does not seem logical to assume that just the "signal" components of an incoming message would be attenuated since this requires prerecognition of the message. A reduced signal to noise ratio would result if the message was attenuated prior to the addition of neural noise but an explicit system of this type is difficult to conceptualize and would hardly be an economical method for identifying and rejecting irrelevant messages.

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Deutsch and Deutsch and Lindsay have raised some criticisms of the paper "Selective attention: perception or response?" by Treisman and Geffen (1967). Briefly, the argument of this paper was as follows: in tasks requiring that attention be selectively directed to one of two competing speech messages, subjects can report little or nothing of the verbal content of the unattended message. This might result from a limit either in perception (as suggested by Broadbent, 1958, in his "filter" model) or in response mechanisms (as proposed by Deutsch and Deutsch, 1963). An experiment was performed to discover which of these stages constituted the main bottleneck. Subjects were presented with two competing speech messages given simultaneously, one in each ear, and were asked to make two responses: the primary response was to repeat back the attended message; the secondary response was to tap whenever a specified target word was heard on either ear. If the main limit was reduced perception of the secondary message, the tapping response to the primary message should be much more efficient than that to the secondary message. But if the main limit lay in the organization of two simultaneous responses, the secondary, tapping response should be equally inefficient whichever message contained the target word, since this word

was the same for the two messages and so should be equally inhibited by the primary repeating response. We argued that our results strongly favoured the limit being perceptual, since subjects tapped to 87 per cent. of primary message targets and to only 8 per cent. presented in the secondary message.

Deutsch and Deutsch and Lindsay raise a number of different theoretical points of some importance. I believe most of the criticisms are based on misunderstandings, so it may be useful for me briefly to clarify our suggestions on each point in turn.

(1) *The effect of importance.* We agree, of course, with Deutsch and Deutsch that the direction of attention can be biased by the relative importance of stimuli. Our interest lay in discovering whether the bias chiefly affects perceptual processing or response mechanisms in the selective listening task. Our instructions were intended to stress the importance of the verbal response to the primary, "attended" message, but to give equal though lesser weight to the tapping responses to targets in both primary and secondary messages. Deutsch and Deutsch suggest that the requirement to repeat as well as tap to the primary targets adds to their importance. This is possible, although our subjects actually seemed more concerned about failures and successes with secondary than primary targets. I agree that it would be useful to repeat the experiment without this requirement and an attempt to do this is referred to below. However it seemed to us that, logically, if a subject's response and memory capacity will support both repeating a word and tapping to a target in 87 per cent. of cases when both are in the primary message, it should support the same level of response when the target is in the secondary message, provided that perceptual analysis is complete in all cases, as Deutsch and Deutsch suggest. It is surprising, then, that only 8 per cent. correct responses were made to secondary targets. Moreover the verbal context of the target words and their homophones affected primary and secondary messages very differently, which is inexplicable if there were no differences in the perceptual analysis of the two messages.

(2) *Interference from secondary targets.* We interpreted the absence of any interference from secondary targets when not tapped to as evidence against full perceptual analysis. Deutsch and Deutsch consider this misinterprets their theory, which, they say, specifically accounts for the lack of such interference. However, our interpretation of their theory was based on their 1963 paper, which quotes Peters's (1954) report of interference by a secondary message as evidence supporting their theory. Moreover we also found that the interference from secondary targets which *were* detected was greater than that from primary targets. We argued that, since the two tapping responses were identical, they should not differ in response or memory load and so detection of the secondary targets must have interfered with *perception* of the primary message.

(3) *The role of memory.* Lindsay argues that our task involves short-term memory. This is true, although it is much less dependent on memory than most tasks which have tested selective attention. The mean response lag for both primary and secondary targets was only 1·2 sec. (3 items) which does not allow much time for decay in a post-perceptual store. The equality of the reaction time to those primary and secondary targets which were detected argues against the intermittent, often delayed monitoring of a stored trace of secondary targets. The time span of interference effects need have nothing to do with storage time; it could equally well be due to losing track, delay in picking up the correct message and so on, even after the interfering item has been forgotten.

(4) *Lawson's results.* Deutsch and Deutsch claim that we have some difficulty in explaining the discrepancy between Lawson's results (1966) with tones as targets and ours with words. So far from this being true, we actually predicted the difference on the basis of Broadbent's theory (see Treisman, 1964*a*), since differences in physical characteristics must be analysed before the "filter" selects the attended message. Evidence supporting this claim is that (*a*) these physical characteristics can all be used as a basis for selection of a message to be attended to (unlike verbal differences such as a change of language); (*b*) they can be reported even for unattended messages; and (*c*) variations in these features can interfere with attention to the selected message (again unlike changes in verbal features of a message). This conclusion is not intuitive, as Lindsay supposes, but based on experimental evidence (Cherry, 1953; Treisman, 1964*b* and *c*). Lindsay also argues that processing capacity is not simply related to stimulus complexity and in support refers to the finding that simultaneous psychophysical discrimination tasks may interfere with one another. But we have not argued, nor would it seem plausible, that there is only one way in which tasks can interfere with one another. The fact that simple discriminations may compete

in threshold experiments does not imply that complexity of perceptual analysis is irrelevant to the difficulty of the task in the selective listening situation we were investigating.

(5) *A test of the theories.* Deutsch and Deutsch's theory is difficult to test, since it normally precludes subjects showing either by response or recall that they have analysed the content of secondary messages. However they do propose a crucial test: our experiment should be repeated with no verbal response made to primary targets, which, I agree, is a necessary control. They also require that the target words should be in a different voice from the rest of the passage, though why this should be necessary to their prediction is not clear. In any case I would also predict that targets in a different voice *would* be detected in the secondary message (for the same reasons as Lawson's tones), and this would possibly be found even if control, non-target words were also used. A difference in voice is one of the physical characteristics which appears to be analysed before the filter, and, if the task makes this cue available, subjects may use it to reduce the ensemble of possible secondary targets which they must monitor to manageable proportions.

A short experiment (which will be reported more fully elsewhere) was run to test the predictions. Sixteen lists of 16 pairs of digits were recorded in a man's voice at 1·8 pairs a sec. The stimuli were recorded on digital tape, equated in length at 250 millisec. by computer compression or expansion and exactly synchronized. At different positions in each list one digit was replaced by a letter. In half the lists this was in the same man's voice as the digits and in half in a woman's voice. Eight lists, randomly chosen, had the letter on one track and eight on the other. The seven subjects were asked to attend to and repeat back the digits on the right ear, but to stop repeating and tap at once if they heard a letter on either ear. This was intended to avoid both response competition and memory limitations. Subjects heard the 16 lists twice through; the primary lists on the first run were the secondary ones on the second run. Subjects were always told which voice would speak the letter and on one run they were told what the letter would be, but they never knew in which ear or which list position it would occur.

The results were as follows: primary message, same voice—71 per cent. correct; primary message, different voice—97 per cent.; secondary message same voice—28 per cent.; secondary message different voice—97 per cent. Subjects found shadowing this computer-synchronized material much more difficult than the prose in the previous experiment and only repeated 74 per cent. of correct items compared to 93 per cent. in the previous experiment. They also frequently switched to the other channel, repeating 13 per cent. of items from the secondary message; this never occurred in the previous experiment. This inability to select the message on the correct ear consistently was most probably due to the accurate synchronization of the digit pairs. If we assume that for at least 13 per cent. of the time the secondary message was actually functioning as the primary message, the true detection rates become at least 79 per cent. for primary targets and at most 20 per cent. for secondary ones. (This assumes that during the 13 per cent. omissions subjects were not switching their attention at all.)

The result confirms our prediction that, when subjects cannot select before the filter on the basis of voice quality, they are unable to detect the majority of secondary targets. Our previous result was not therefore due to the requirement to repeat as well as tap to primary targets, and the discrepancy from Lawson's results with tones is not explained by this suggested difference in relative "importance." With targets in a different voice, which made preselection possible, subjects detected almost all the targets in both ears. This argues against an inherent response limit and supports the theory of a perceptual limit arising chiefly at the stage where the verbal content is identified.

(6) *Selection by reduction in signal-to-noise ratio of secondary messages.* First, we did not wish to imply, as Lindsay suggests, that the possible difference in the d′ statistic was evidence for perceptual selection. Our point was that—given that the rest of our results showed a perceptual limit—then the form it took appeared to be a reduction in S/N ratio for secondary messages (although the evidence is still admittedly tentative). Both Deutsch and Deutsch and Lindsay raise a more general point. They doubt that any economy in perceptual analysis could be gained from a reduction in S/N ratio, and claim that this would have the opposite effect of making rejection more laborious. But this criticism seems to be based on unnecessary assumptions. Talk of disruption by noise, as though detection were obligatory and noise *had* to be combated, seems misconceived. The assumption we made was that words presented to either channel are exposed to a series of detection processes which can either detect or fail to detect, and no special disruption is entailed by either

outcome. A possible system for speech recognition consists of a hierarchical arrangement of tests for the critical features distinguishing phonemes, words or phrases. If unshadowed words, with their low S/N ratio, can be discarded at the earliest stages when they fail the most general tests, this would eliminate any interference at subsequent stages of speech analysis. This rejection of irrelevant words would be unfortunate in the case of very important items (own names, target words etc.) but in these cases the effect of the lowered S/N ratio could be combated to some extent by maintaining the criteria for their detection especially low. Thus, although detection of these important words in the secondary message would be less frequent than in the primary message (as it is in fact), there would still be considerable economy, in that most of the secondary stimuli would not be analysed in any detail. There is some evidence that a noisy message does in fact interfere less with perception of a competing message than one that is clear and easy to perceive (Treisman, 1964*b*).

Finally Lindsay would like some clarification of the notion of attenuation, or reduction in effective S/N ratio. We deliberately left this suggestion as general as possible, since behavioural evidence is unlikely to support one precise alternative against another. However, his suggestion of attenuation followed by the addition of noise was one possibility we had in mind; in a multi-stage perceptual system this process does not seem to us either implausible or "difficult to conceptualize."

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