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16. Abstract

Although air traffic controllers are often required to perform in the presence of distracting stimuli, no adequate measures of distraction susceptibility exist. In the present study, 50 male subjects were tested to determine whether the interference effect produced by the Stroop color-word test (a potential measure of distraction susceptibility) might be enhanced through the use of simultaneously-presented, conflicting auditory stimuli. When instructed to respond only to the hue of visually-presented color-words printed in incongruent inks, neither task-related (conflicting color names) nor task-unrelated (random numbers) auditory stimuli resulted in any increase in the Stroop interference effect, and there were no indications of an increase in autonomic indices of arousal. A subsidiary aspect of the study revealed the Stroop interference effect did not occur when the irrelevant stimuli were shifted from the visual to the auditory modality. It was concluded that the use of simultaneous auditory stimuli, which are similar but irrelevant to the visual stimuli employed, contribute nothing additional to the basic Stroop test in terms of either task interference or level of arousal.

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EFFECTS OF CONFLICTING AUDITORY STIMULI ON COLOR-WORD INTERFERENCE AND AROUSAL

I. Introduction.

Air traffic controllers are often required to maintain sustained attention to visual tasks in the midst of a variety of extraneous visual or auditory stimuli. Such stimuli, by momentarily distracting the controller from his primary tasks, could have potentially serious consequences. While it is commonly believed that some individuals are more easily distracted than others, relatively little research has been concerned with individual differences in susceptibility to distraction. Although there are signs of increasing interest in this area (Baker and Madell, 1965; Bee, 1966, 1968; Mandell, 1966), no study thus far has provided much information relative to the consistency of individual differences in susceptibility across different types of distraction conditions. If it could be established that these differences represent consistent behavior patterns, this would have definite implications for selection of air traffic control personnel.

One of the most promising tests for the systematic study of distraction and distraction susceptibility would appear to be the color-word interference test (Stroop, 1935). This test requires a high degree of concentration and has been suggested as a measure of an individual's ability to deal selectively with competing stimuli (Mandell, 1966) or of his interference proneness (Jensen and Rohwer, 1966). It may also reflect ability to make rapid decisions in the face of conflicting information (Grand and Segal, 1966). As such, the test would appear to tap qualities relevant to air traffic control performance.

The basic test consists of three parts: (1) reading the names of colors printed in black and white; (2) naming the colors in which circles or squares are printed; (3) naming the hue in which incongruent color-words are printed. The test is generally scored in terms of the difference in time required to complete parts 2 and 3. The difficulty involved can be appreciated by considering the problems associated with suppressing the tendency to name the printed words themselves when instructed to respond only to the colors in which the words are printed.

In the most typical versions of the Stroop test, the subject's (*S's*) responses are vocal and the score is simply the number correct in a given amount of time. In order to provide a version which would have greater flexibility as a research instrument, a task was developed which (a) allowed individual presentation of each stimulus with precise control over stimulus duration and inter-stimulus intervals, (b) was capable of being either experimenter or subject paced, and (c) yielded a measure of response time to each stimulus.

As noted, a primary purpose in developing this "performance" version of the Stroop test was to devise a versatile task which could be used in subsequent studies directly concerned with individual differences in distraction susceptibility. However, in order to possibly increase the test's effectiveness for this purpose, it seemed desirable to determine the extent to which the color-word intereference effect might be augmented by simultaneous auditory presentation of color names which conflicted with the visual stimuli. Thus, Frankenhaeuser, Fröberg, Hakdahl, Rissler, Björkvall, and Wolff (1967), and others (Rissler, 1965) have employed a version of the Stroop test similar to the one developed here except that conflicting color names are auditorily presented simultaneously with the visual stimuli. They have obtained significantly elevated catecholamine levels with their version which suggests that it is at least moderately stressful. In none of their studies, however, do they actually report data which would enable a determination of the relative increase in stress or performance interference resulting from the additional auditory stimuli. Presumably, if the additional stimuli act as distractors and compete with the visual task, this should increase performance impairment as well as stress level.

The present study, then, was designed to determine whether irrelevant auditory stimuli of differing similarity to the visually presented color-words do have an influence on task performance when these are presented simultaneously with the visual stimuli. Two additional questions were also asked: (1) Is the Stroop interference effect dependent upon the irrelevant stimuli being presented within the same modality? Thus, would the interference effect be completely eliminated or would it be simply reduced if the irrelevant stimuli were shifted to the auditory sense? (2) Does the Stroop test itself act as a task induced stressor, i.e. does the interference resulting from the color-word stimuli produce corresponding changes in autonomic indices of arousal?

II. Method.

Subjects. Fifty paid male college students between the ages of 18 and 25 served as *Ss*. All were right-handed with no reported color-vision deficiencies. Each *S* was assigned to one of five groups on a simple rotational basis yielding a final *N* of 10 *Ss* per group.

Apparatus. Located in one room was the *S*'s console containing a rear projection screen and a Lafayette Model KT–800 Automatic Projection Tachistoscope. The *S* was seated in front of the console approximately 22 inches from the screen. His right hand rested on a shelf directly below

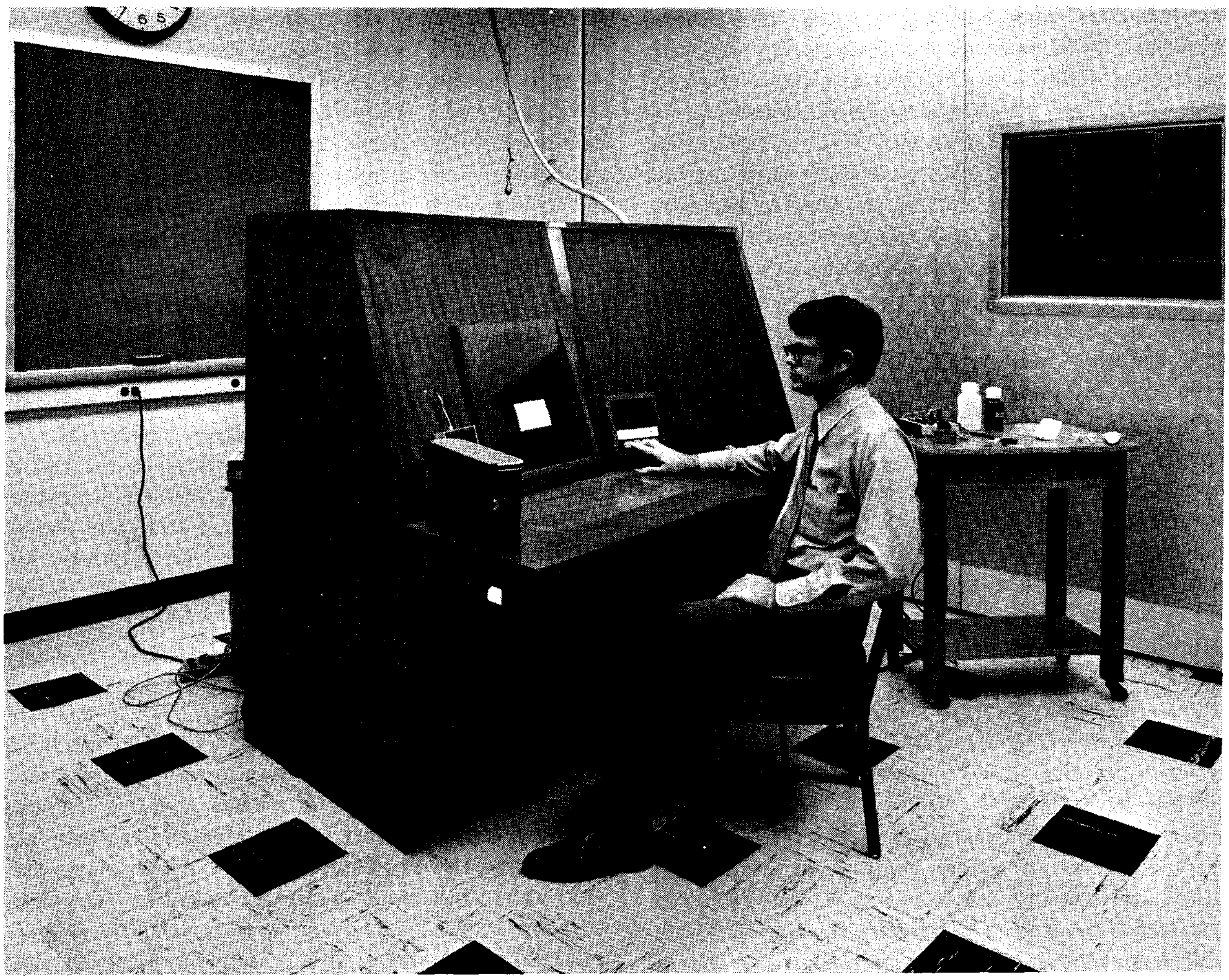

FIGURE 1. Photograph of subject's console. The window at the right was used for one-way observation.

four buttons which actuated separate microswitches. The stimulus words were printed directly above each button. A speaker for presenting either task instructions or auditory stimuli was placed to the left of the projection screen. Figure 1 shows a photograph of the *S's* console.

The task programming equipment, as well as the equipment for recording the physiological and performance data, were located in an adjoining room. The method of programming the stimuli was as follows: Successive low frequency pulses from an audio oscillator were initially recorded on one channel of a stereo tape recorder. The interval between pulses was a constant three seconds. During playback each pulse actuated a sensitive relay which in turn triggered a bank of three DSI Model D–501 Time Interval Generators. These were used to activate the tachistoscope shutter and advance the slides. The duration of stimulus exposure was one--half second. The other channel of the tape recorder was used for instructions and for auditory stimuli.

Response time to each stimulus was measured to the nearest $\frac{1}{100}$ second by means of a Welford Mark V SETAR (Welford Bioelectronics Enterprises) and punched on paper tape. The tape was later fed through a Friden Flexowriter which printed response time as well as recording which of the keys was pressed.

A Beckman Type R dynograph recorded the physiological variables. The electrocardiogram was obtained from Beckman biopotential electrodes attached to the lateral walls of the *S's* chest. Respiration was measured from two

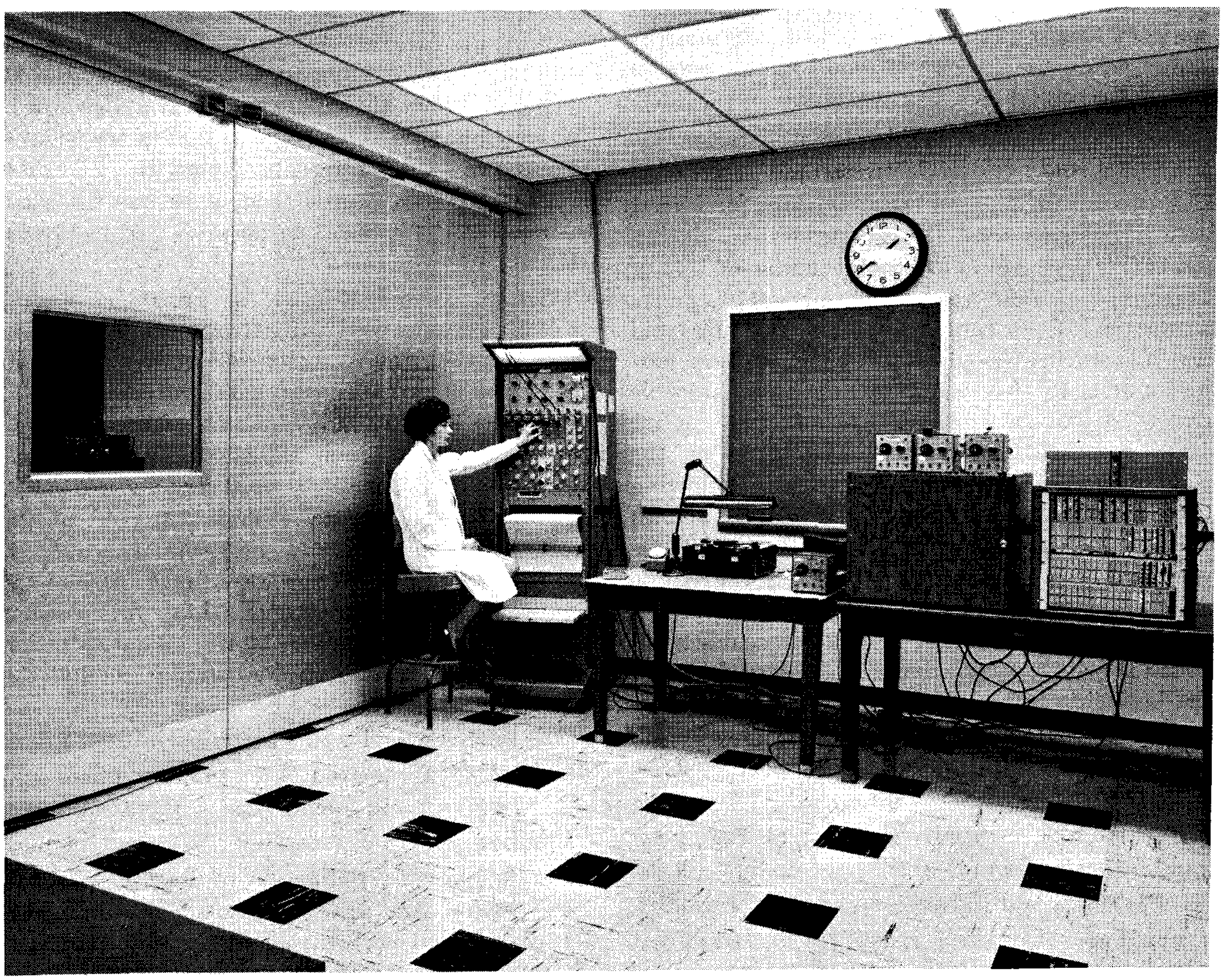

FIGURE 2. Photograph of task programming and physiological recording equipment.

mercury-in-vinyl gauges; one was attached at the thoracic and the other at the abdominal level. The gauges were connected to two specially constructed bridge couplers. Beckman electrodes for electromyographic recording were also attached to the chin and forehead. Recordings obtained from these latter electrodes as well as those from the thoracic respiration gauge were used for exploratory purposes and will not be reported here. The physiological recorder and task programing equipment are shown in Figure 2.

Visual stimuli were of three basic types: (1) the words BROWN, GREEN, ORANGE, or PURPLE printed in black letters; (2) colored rectangles corresponding to the colors of these words; and (3) the above words printed in incongruent ink colors, e.g. the word BROWN would be printed in either green, orange, or purple ink. Stimuli were photographed and reproduced on 35 mm slides. All stimuli were of constant height (27 mm) and width (68 mm) as projected on the screen. A small white cross on the screen served as a fixation point.

Procedure. After the initial orientation instructions, the various electrodes and respiration belts were attached and the procedure for Part I was explained. The *Ss* were told that, during this part, each stimulus would consist of one of the following four words—brown, orange, green, or purple. Each time a stimulus was presented the *S* was instructed to push the button corresponding to that word as rapidly as possible and then look back at the fixation spot. After every response the *S* rested his fingers on the shelf immediately below the buttons. Following four practice stimuli, the set of 72 stimuli, all printed in black letters, was presented. These were arangred in a quasi-random order with the restrictions that each stimulus appear an equal number of times and that no two adjacent stimuli be the same. A three-minute rest period followed the last slide which allowed time for the experimenter to change stimuli and make other necessary equipment adjustments. All *Ss* received the same stimulus order.

Part II was essentially the same as Part I except that the stimuli consisted of the colored rectangles and a different random order was used.

For Part IIIa, each group received different stimuli and/or instructions. These were as follows:

Group A received the same stimuli (colored rectangles) in the same order as they were presented in Part II. They were told that the purpose of this part was to check the reliability of Part II.

Group B was administered the set of stimuli employed with Group A except that each time a visual stimulus was presented the name of one of the four colors was simultaneously spoken over the speaker. The *S* was instructed to ignore the spoken word and respond only to the color of the rectangle projected on the screen. The auditory stimuli were arranged in a quasi-random fashion similar to that employed with the visual stimuli. In every case the auditory stimulus was the name of an incongruent color.

Group C was presented the conventional Stroop color-word stimuli, i.e. names of the four colors printed in incongruent inks. The *Ss* were instructed to ignore the word itself and respond only to the *color* of the word. In order to make conditions comparable to Groups A and B, the order in which the colors of the stimulus words were arranged was the same as that of the colored rectangles used for Groups A and B. Likewise, the order of the words themselves was the same as that of the spoken words presented to Group B.

Groups D and E used the same sequence of stimuli as were used with Group C. The difference was in the addition of auditory stimuli presented simultaneously with the visual. For Group D these stimuli consisted of the names of the four colors which were always incongruent with both the projected word and its hue. For Group E the auditory stimuli consisted of the following four randomly chosen numbers: 18, 83, 56 and 25. Both groups were told to ignore the auditory stimuli and respond only to the color of the visually presented word. Randomization of the auditory stimuli was similar to that described previously.

As with Parts I and II, the *Ss* in each group in Part IIIa received four practice trials and 72 visual stimuli (with or without auditory stimuli).

Following the completion of Part IIIa, *Ss* in each group were informed that they would now be required to perform again the task they had just completed, only at a much faster pace. After four practice trials each group received the same stimuli they were presented during the preceding part except that the inter-trial interval was reduced from three seconds to one and one-half seconds.

III. Results.

Mean reaction times for parts II, IIIa, and IIIb are shown in Table 1. An analysis of variance of part II revealed no differences between the groups ($F=1.29$; $p>.05$) in their response times to the colored rectangles. For part IIIa, however, the differences between the groups were significant ($F=14.6$; $p<.01$). A Newman-Keuls test (Winer, 1962) revealed that groups A and B were different from groups C, D, and E ($p<.01$), but there were no significant differences between A and B or between C, D, and E. Presenting the stimuli at twice the initial rate resulted in no apparent change in the basic relationships between the five groups. The analysis of variance for part IIIb was significant ($F=12.56$; $p<.01$) and Newman-Keuls tests again revealed groups A and B to differ from groups C, D, and E ($p<.01$) with no differences between A and B or between C, D, and E.

TABLE 1. Mean response time in seconds for each group.

Part	Group				
	A	B	C	D	E
II	0.78	0.73	0.85	0.80	0.80
IIIa	0.72	0.72	1.02	0.94	0.98
IIIb	0.76	0.74	0.95	0.86	0.90

Mean levels of heart rate for all groups during parts II, IIIa, and IIIb are shown in Table 2. A repeated measures two-way analysis of variance revealed no significant differences between groups ($F=1.01$; $p>.05$) and no significant interaction ($F=2.21$; $p>.05$). There was, however, a highly significant difference between parts ($F=44.97$; $p<.01$). The analysis of variance on the respiration data shown in Table 3 yielded similar results. Thus, the difference between parts was quite significant ($F=34.96$; $p<.01$), while neither the group ($F=1.15$; $p>.05$) nor interaction ($F<1.00$) effects were significant. Examination of Tables 2 and 3 clearly indicates that these significant effects were the result of the increase in both heart rate and respiration rate during part IIIb.

TABLE 2.—Mean heart rate in beats per minute for each group.

Part	Group				
	A	B	C	D	E
II	72.4	79.3	79.0	74.4	68.5
IIIa	72.0	79.2	77.8	75.7	71.1
IIIb	75.1	83.4	81.7	82.6	76.3

TABLE 3.—Mean respiration rate in cycles per minute for each group.

Part	Group				
	A	B	C	D	E
II	20.5	18.8	18.2	18.9	20.2
IIIa	19.7	19.5	17.2	19.7	20.2
IIIb	22.7	22.0	19.0	23.1	23.5

IV. Discussion.

The results revealed that the method employed in this study for presenting the Stroop color-word stimuli was successful in eliciting the characteristic interference effect. However, when auditory stimuli were simultaneously presented with the visual color-word stimuli, neither the task-related (incongruent color names) nor the task-unrelated (random numbers) stimuli had any apparent effect on performance whatsoever. This lack of effect held regardless of whether the stimuli were presented at a moderate pace or at a quite rapid one. In addition, the data also revealed the Stroop effect to occur only when both relevant and irrelevant stimuli were presented within the same (visual) modality. Thus, shifting the irrelevant stimuli to the auditory modality completely eliminated the interference effect.

With regard to the physiological measures taken, none of the groups differed in either heart rate or respiratory rate during either the first or second half of part III, although the faster pace of part IIIb resulted in uniformly higher levels for all groups.

This finding is rather surprising in view of the apparent frustration and tension which has been reported to attend Stroop performance (Klein, 1964) and in view of the elevated catecholamine levels found by the previously noted investigators (Frankenhaeuser, et al., 1967) using a similar version of the Stroop test. However, in observing the behavior of the *Ss* in those groups receiving the color-word stimuli and in questioning them later, it appeared that they were often less emotionally "upset" than they were surprised and even somewhat amused at their difficulty in responding to the hue of the color-word stimuli. This suggests that the perceptual conflict produced by the Stroop stimuli may reflect attentional processes which are only minimally associated, if at all, with shifts in general level of "arousal." There is increasing evidence that changes in attentional demands may produce significant changes in task performance which are not accompanied by any observable shift in physiological indicants of activation (Malmo, 1966).

The present study suggests that the elevated catecholamine levels found by Frankenhaeuser and her co-workers may be more the result of task pacing and/or the instructions employed than any "stress" resulting from the Stroop stimuli themselves. During the second half of part III, Group D received essentially the same visual and aduitory stimuli at approximately the same pace as employed by the above investigators. Yet, although both heart rate and respiration were increased by the more rapid rate of stimulus presentation, this increase did not differ from that of the control group administered the colored rectangles. Finally, it should be noted that Frankenhaeuser et al. administered instructions to their *Ss* which implied that students in general were able to perform the task perfectly after some practice. Because of the frustrating nature of the task itself, such instructions could be quite threatening and might well have accounted for, or at least contributed to, the increase in catecholamine levels.

The results clearly suggest that the use of simultaneous auditory stimuli, which are similar but irrelevant to the visual stimuli employed, contribute nothing additional to the basic Stroop test in terms of either task interference or level of arousal. This, of course, should not be taken to imply that auditory stimuli per se are necessarily ineffective as distractors. Broadbent (1958), for example, has indicated certain stimulus conditions (e.g. intensity levels above 90 db, long duration exposure, sudden onset or offset, frequencies above 2000 Hz, etc.) which have been shown to impair performance. The present study was concered only with the limited question of whether the Stroop interference effect might be enhanced through simultaneous presentation of irrelevant, but similar, stimuli. Research is currently being planned to determine whether this test, which was shown to be quite uninfluenced by the particular "distractors" employed here, is predictive of performance on other tasks under conditions of auditory distraction more likely to produce impairment.

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