Effect of irrelevant information on the processing of relevant information: Facilitation and/or interference? The influence of experimental design

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Previous studies have provided conflicting evidence concerning the question of whether irrelevant information can facilitate the processing of relevant information in a choice reaction time task. Results of the present study demonstrated that indications of facilitation and/or interference were dependent on the context in which baseline trials were administered. Three groups of 24 subjects pressed a left- or right-hand key in response to the onset of an X or O that was accompanied by a monaural or binaural tone. The monaural tone provided an irrelevant directional cue since, on some trials, it was ipsilateral to the correct response (corresponding trials), while, on other trials, it was contralateral (noncorresponding trials). When binaural (baseline) trials were presented in the same block as the monaural trials, data suggested that the directional cue produced both facilitation and interference. However, when baseline trials were presented in one block, and corresponding and noncorresponding trials were mixed together in another block, data suggested an interference effect only. The difference was attributed to differences in the degree of stimulus uncertainty within a block of trials.

It is well established that certain visual and auditory displays provide irrelevant cues that interfere with information processing (Clark & Brownell, 1975; Dyer, 1973; Jensen & Rohwer, 1966; Simon, 1970). But can the presence of irrelevant cues also facilitate the processing of relevant information? There is considerable evidence that simple and discrimination reaction time (RT) can be shortened by presenting an accessory stimulus at the same time as a primary stimulus but to a different sensory modality (Nickerson, 1973). Whether an irrelevant cue can also facilitate information processing in a choice RT task is less clear. The answer may well depend on the definition of facilitation. The present paper focuses on the problem of choosing an appropriate point of comparison or baseline for determining whether facilitation and/or interference occurs in a choice RT task. The determination of an appropriate baseline is, of course, a common problem in research on information processing (e.g., Herman & Kantowitz, 1970).

Our interest in the facilitation and/or interference question arose from a series of studies concerned with the effect of an irrelevant directional cue on

processing a relevant symbolic cue in an auditory display. In our first study, subjects were asked to press a left- or right-hand key in response to monaurally presented commands of "left" or "right." Responses were significantly faster when the content of the command corresponded with the ear stimulated (i.e., "left" in left ear or "right" in right ear) than when it did not (i.e., "left" in right ear or "right" in left ear) (Simon & Rudell, 1967). Comparable results were obtained in an analogous visual task in which left or right commands were presented to the left or right eye (Craft & Simon, 1970) and in tasks in which a visual stimulus that commanded a left- or right-hand keypress was accompanied by a simultaneous monaural tone (e.g., Simon & Craft, 1970). Clearly, in all of these situations, an irrelevant directional cue was affecting the time required to process a relevant symbolic cue. What is not clear is whether the irrelevant directional cue facilitated information processing on trials in which it corresponded with the relevant symbolic cue and/or whether it interfered with processing on trials in which it did not correspond with the relevant symbolic cue. To answer this question requires establishing a baseline RT that is free from any influence of the irrelevant cue and also free from other sources of bias.

In some of our studies, in which the ear stimulated provided the irrelevant directional cue, we included binaural trials to provide a baseline since there is no

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directional cue associated with a binaural tone. In other studies of visual RT in which monaural trials provided the irrelevant directional cue, we included binocular trials to provide a baseline. Results of these studies have produced conflicting evidence concerning the facilitation and/or interference issue. In one group of studies, it appeared that the irrelevant directional cue interfered with responding on the noncorresponding trials and also facilitated responding on the corresponding trials (Acosta & Simon, 1976; Simon & Craft, 1970; Simon & Pouraghabagher, 1978). In another pair of studies, it appeared that the irrelevant directional cue interfered with responding on the noncorresponding trials but did not facilitate responding on the corresponding trials (Craft & Simon, 1970; Simon & Small, 1969).

The purpose of the present study was to identify the reason for the conflicting evidence from these two groups of studies. An examination of the procedures followed suggested that our experiments had differed from one another in two respects, either of which might have accounted for the different results. One was the experimental design, or, more specifically, the context in which the baseline trials were administered. The other was the paradigm used, that is, whether the directional cue was provided by an irrelevant dimension of the stimulus itself or by a simultaneous but irrelevant stimulus to another sensory modality. It is difficult to evaluate the effect of these factors separately, because, in our previous studies, we have tended to employ one experimental design with one paradigm and another design with the other. Specifically, when the directional cue was provided by a simultaneous but irrelevant stimulus to another sensory modality, we have always employed a design in which the baseline, corresponding, and noncorresponding trials were presented together in the same block. In these studies, the irrelevant directional cue seemed to produce both facilitation and interference. On the other hand, when the directional cue was an irrelevant dimension of the relevant stimulus, we have usually employed a design in which the baseline trials were presented in a separate block from trials in which the directional cue was present. Results of these studies suggested that the irrelevant directional cue produced interference but not facilitation.

There are two exceptions to this association between the design and paradigm, on the one hand, and results, on the other. One was a study in which manipulation of interaural phase difference was used to alter the apparent source of a binaural tone (Simon, Craft, & Small, 1971, Experiment 2). The baseline trials (i.e., 0- and 180-deg phase-shift settings) were included in the same block as the corresponding and noncorresponding trials, and results suggested that the irrelevant directional cue produced inter-

ference but not facilitation. It may be that these results differed from those of other studies that employed the same experimental design because the directional cue produced by the phase-shifting device was not as potent as that produced by a monaural tone. The other exception was a study employing the same pairing of paradigm and design as the previous one but which produced evidence suggesting that both facilitation and interference may occur (Simon, Acosta, Mewaldt, & Speidel, 1976). This latter study suggested that design rather than paradigm might be the critical factor.

The present study employed the paradigm which, in the past, had provided consistent evidence for both facilitation and interference; that is, the directional cue was provided by an irrelevant auditory stimulus which was presented simultaneously with a relevant visual stimulus. With this paradigm held constant, we manipulated the context in which the baseline trials were administered to determine whether different contexts produced different results with regard to facilitation and/or interference.

METHOD

Subjects

The subjects were 72 right-handed female students enrolled in an introductory psychology course at the University of Iowa. All subjects reported having normal or corrected-to-normal vision and hearing.

Apparatus

The choice RT apparatus consisted of a visual display module, warning light, two response keys, and an audio oscillator. The display module, a Monsanto MDA-111 Alphanumeric Readout with a 5×7 matrix of photodiodes, was mounted at eye level on a vertical panel approximately 50 cm from the subject. The module displayed the characters X or O, which measured 8.9 mm in height and had a stroke width of 1.0 mm. A green warning light was installed 5 cm directly above the display module. Two micro-switch keys, which subjects operated with their left and right index fingers, were positioned on a table 9 cm to each side of the display.

On each trial, the visual stimulus was accompanied by the simultaneous onset of a 625-Hz tone generated by a Hewlett-Packard Model 200 AB audio oscillator. The tone was presented monaurally or binaurally through Grason-Stadler TDH39 10Z earphones. On monaural trials, the output level was 100 dB SPL (re .0002 μ bar), while, on binaural trials, the output level was reduced to 97 dB SPL to approximate the loudness of the monaural trials.

A series of trials was preprogrammed on punched paper tape that was read by a Digitronics Model 2060 perforated tape reader. The RTs (in msec) and responses were recorded on paper tape by means of a Roytron Model 518 tape punch. BRS-Foringer solid-state logic (Digibits 200 Series) provided overall control of the stimulus presentation and data acquisition.

Procedure and Experimental Design

Subjects were instructed that they would see an X or an O and simultaneously hear a tone in one or both ears and that their task was to make the correct response to the visual stimulus as rapidly and accurately as possible. Half of the subjects were told to press the right key when they saw an X and the left key

when they saw an O, while the other half were given the opposite stimulus-response (S-R) rule.

Each subject performed on three blocks of trials, each block consisting of 24 warm-up trials and 60 test trials. Each trial consisted of a 150-msec warning light followed 1 sec later by either an X or an O and, simultaneously, a tone in the left ear, the right ear, or both ears. Two seconds after the subject's response, the warning light for the next trial was presented. Prior to the first block of trials, 12 practice trials were presented to familiarize subjects with the task.

Over the course of the 180 test trials, each subject responded 30 times to each of the six possible combinations of the two visual stimuli and the three tone locations. The manner in which the six stimulus combinations were grouped for presentation (i.e., blocked) defined the major independent variable in this study.

Subjects were divided at random into three groups of 24 each. In one group, the binaural (B), left-ear (L), and right-ear (R) trials were all mixed together in each of the three blocks. For shorthand purposes, we will refer to this group as the BLR group. In each block, the six combinations of the two visual stimuli and the three tone locations were each presented 10 times in a predetermined random sequence. Prior to each block, subjects were told that the visual stimulus would be accompanied by a tone to the left ear, to the right ear, or to both ears.

In a second group, the binaural trials were presented in one block and the left- and right-ear trials were combined (i.e., mixed together) in the other two blocks. For shorthand purposes, this group is labeled the B-LR group. The two visual stimuli each appeared 30 times in each block. Each monaural block contained all four combinations of the two visual stimuli and the two tone locations, each occurring 15 times in a predetermined random sequence. Subjects were told prior to the binaural block that the visual stimulus would be accompanied by a binaural tone and were told prior to each monaural block that the stimulus would be accompanied by a tone to either the left or right ear. Order of presentation of the three blocks was counterbalanced.

In a third group, the binaural, left-ear, and right-ear trials were each presented in a separate block. This group will be referred to as the B-L-R group. In each block, each visual stimulus appeared 30 times in a predetermined random sequence. Prior to each block, subjects were informed of the ear(s) in which they would hear the accompanying tone. Order of presentation of the three blocks was counterbalanced. The B-L-R and B-LR groups were identical in terms of the context in which baseline trials were presented, but differed in terms of the context of the monaural trials.

The experimental design consisted of two between- and two within-subjects factors. One between-subjects factor was trial context as described above, that is, BLR, B-LR, and B-L-R. The other was S-R rule; that is, half of the subjects in each group were instructed to press the right key in response to the X and the left key in response to the O, while the other half were given the opposite S-R rule. The within-subjects factors were visual command (i.e., X or O) and ear stimulated (i.e., left, right, or both).

RESULTS

Median RTs were computed for each subject for three types of trials: (1) corresponding trials in which the correct keypress response was ipsilateral to the ear stimulated (i.e., left-key responses when the tone was in the left ear and right-key responses when the tone was in the right ear); (2) noncorresponding trials in which the correct keypress response was contralateral to the ear stimulated (i.e., left-key responses when the tone was in the right ear and right-key responses when the tone was in the left ear);

and (3) baseline trials in which the binaural tone accompanied the visual stimulus to respond "left" or "right." The binaural trials are called baseline trials because there is no location cue associated with a binaural tone. They therefore provide a point of comparison for determining whether the irrelevant directional cue produced by the monaural tone had a facilitative or interfering effect on visual RT. Data from trials on which errors were made (3.6% of the trials) were excluded from the analyses. There was no difference in error rate among the three experimental groups.

Figure 1 shows the mean of the median RTs for corresponding, noncorresponding, and baseline trials for the three experimental groups. The data were subjected to an overall analysis of variance as well as follow-up analyses as appropriate. The overall analysis revealed significant effects of trial type [$F(2,132) = 41.69, p < .001$] and context [$F(2,66) = 5.68, p < .01$] and also a trial type $\times$ context interaction [$F(4,132) = 8.40, p < .001$]. Because of the interaction, separate analyses of variance were conducted for each treatment group to examine the effect of trial type in the separate contexts. An analysis of variance of the BLR group revealed a significant effect of trial type [$F(2,44) = 35.59, p < .001$]. Follow-up Scheffé contrasts indicated that corresponding RT (412 msec) was significantly ($p < .01$) faster than baseline RT (428 msec) and that baseline RT was also significantly ($p < .01$) faster than noncorresponding RT (450 msec).

An analysis of variance of the B-LR group also revealed a significant effect of trial type [$F(2,44) = 23.20, p < .001$]. Follow-up Scheffé contrasts revealed no difference between corresponding (406 msec)

Figure 1. RT on corresponding, noncorresponding, and baseline trials for the three treatment groups. The number inside each bar specifies the degree of stimulus uncertainty, that is, the number of different kinds of trials in the block from which the RT was obtained.

and baseline (405 msec) RT, but a significant difference ($p < .01$) between the mean of these RTs and noncorresponding RT (447 msec). A separate analysis established that order of administration of trial blocks to the B-LR group had no effect.

An analysis of variance of the B-L-R group revealed no effect of trial type [$F(2,44) = 3.03$, $p > .05$], that is, no difference between corresponding (395 msec), noncorresponding (398 msec), and baseline (385 msec) RT. A separate analysis established that the order in which the trial blocks were administered to the B-L-R group had no effect.

Separate analyses of variance were conducted to determine the effect of context on each trial type. There was no context effect for corresponding trials ($F < 1$); that is, there was no difference between BLR (412 msec), B-LR (406 msec), and B-L-R (395 msec). There was a significant context effect for noncorresponding trials [$F(2,66) = 9.16$, $p < .001$]. Follow-up Scheffé contrasts indicated no difference between noncorresponding trials in the BLR and B-LR contexts (450 vs. 447 msec), but both of these were significantly ($p < .01$) slower than in the B-L-R context (398 msec). There was also a significant context effect for baseline trials [$F(2,66) = 7.79$, $p < .001$]. Scheffé contrasts revealed no difference between baseline trials in the B-LR and B-L-R groups (405 vs. 385 msec), which was as expected since the context for the baseline trials was identical in these two groups. The average RT of baseline trials when presented in a separate block (B-LR and B-L-R groups) was significantly ($p < .01$) faster than the RT for these same trials when administered in the context of monaural trials, that is, the BLR group (395 vs. 428 msec).

DISCUSSION

The major purpose of this study was to determine the reason for the conflicting evidence from previous research on the question of whether an irrelevant directional cue can facilitate the processing of a relevant symbolic cue. Results indicated that the crucial factor responsible for the discrepant findings was the context in which the baseline trials were administered. In the present study, subjects pressed a left- or right-hand key in response to a visual stimulus that was accompanied by the simultaneous onset of a monaural or binaural tone. In previous studies, this paradigm had always produced a picture suggesting that the irrelevant directional cue interfered with responding on noncorresponding trials but also facilitated responding on corresponding trials.

When we presented the binaural trials in the same block as the monaural trials (i.e., BLR group), our results suggested both facilitation and interference. Specifically, noncorresponding trials were significantly slower than binaural trials, while correspond-

ing trials were significantly faster than binaural trials. Thus, our present results replicated findings from previous studies that had employed the same experimental design and the same paradigm.

However, when the binaural trials were presented in one block and the corresponding and noncorresponding trials were mixed in a separate block (i.e., B-LR group), a different picture emerged—one that suggested an interference effect but no facilitation. Specifically, noncorresponding trials were significantly slower than binaural trials, but corresponding trials did not differ from binaural trials. These results replicated findings from previous studies that had employed the same experimental design but used a different paradigm (i.e., irrelevant directional cue and relevant symbolic cue in the same modality). Thus, we conclude that the conflicting evidence noted previously was due to a difference in experimental design (i.e., context) and not to a difference in paradigm.

When corresponding, noncorresponding, and binaural trials were each presented in a separate block (i.e., B-L-R group), there was no evidence for either facilitation or interference. From an information theory perspective, this result was not unexpected since, with tone location invariant within a block, there were 0 bits of irrelevant information in each block. Yet, there are data from a previous study that indicate that an irrelevant directional cue affects processing a relevant symbolic cue under conditions similar to those of the B-L-R group. Simon and Rudell (1967) had subjects press a left- or right-hand key in response to the words "left" or "right," which were presented to the left or right ear. In their Experiment 2, left-ear trials were presented in one block and right-ear trials were presented in a separate block, and instructions prior to each block stressed the fact that the verbal commands would be heard in the left ear only or the right ear only, as the case might be. Reaction time was significantly faster when the content of the command corresponded to the ear stimulated than when it did not, although the effect of the irrelevant location cue was not as marked as in a companion experiment in which left- or right-ear trials were mixed in the same block. The apparent discrepancy between the Simon and Rudell findings and the present results for the B-L-R group may be due to the fact that it is more difficult to separate relevant from irrelevant cues when their respective inputs involve the same sensory channels than when they involve different sensory modalities.

The separate analysis of binaural (baseline) RT as a function of context suggested that the degree of stimulus uncertainty within a block was responsible for the differing indications regarding the facilitation-interference question. Binaural trials were significantly faster when they were presented in a separate block (B-L-R or B-LR groups) than when they were

presented in the context of the monaural trials (BLR group). It seems likely that this RT difference is related to the fact that the binaural block in the B-L-R and B-LR groups contained only two kinds of trials, whereas the binaural trials in the BLR group were presented in a block containing six kinds of trials. The effect of uncertainty or number of alternatives on RT is well established (Bricker, 1955; Garner, 1962; Merkel, 1885, cited in Woodworth, 1938).

Any post hoc look at the possible relationship between stimulus uncertainty, on the one hand, and noncorresponding and corresponding RT, on the other, must be interpreted with great caution because the comparisons are confounded by the effect of the irrelevant directional cue; that is, it affected the BLR and B-LR groups but not the B-L-R group. Noncorresponding RT in the B-L-R group, in which the block contained two kinds of trials, was significantly faster than in the B-LR or BLR groups, in which the block contained four and six kinds of trials, respectively. Corresponding RT did not vary significantly as a function of context (uncertainty), although there was a trend in the direction of increasing RT with increasing stimulus uncertainty. There is, in fact, evidence that stimulus uncertainty has a differential effect on compatible and incompatible tasks. For example, Morin and Forrin (1962) showed that increasing the number of different trials in a block from two to four had no effect on a compatible task (naming numerals) but did produce slower RT on an incompatible task (making numerical responses to geometric symbols). Leonard (1959) also found that the increase in RT usually associated with an increase in the number of stimulus-response alternatives did not hold for a highly compatible task.

In view of the possible effect of stimulus uncertainty on the comparisons, what is the appropriate experimental design for determining whether an irrelevant directional cue can facilitate the processing of relevant information? In the B-L-R design, the corresponding, noncorresponding, and binaural trials are equivalent in the degree of stimulus uncertainty, but, because the location cue is invariant within a block, no irrelevant information is present in the information theory sense. Clearly, then, this design is not relevant for examining the effect of the irrelevant directional cue. The B-LR design seems flawed, as well, since the binaural block involves a lesser degree of stimulus uncertainty than the block containing both corresponding and noncorresponding trials (two vs. four kinds of trials). Thus, if binaural RT were faster than monaural RT simply by virtue of the lesser degree of uncertainty, then employing it as a baseline would bias the picture against concluding that facilitation occurred on the corresponding trials. The BLR design has the advantage that

corresponding, noncorresponding, and binaural trials share the same context and thus are equivalent in terms of degree of stimulus uncertainty. There is, however, a potential problem associated with this design. It is conceivable that responses on the binaural trials may be slowed simply because they are presented in a context that contains an irrelevant directional cue. In other words, the result that we might label facilitation (corresponding RT faster than binaural RT) might not be facilitation at all but, rather, a slowing of binaural RT. There is evidence that relatively compatible responses are sensitive to contextual association with incompatible responses (Morin & Forrin, 1962). This would suggest that the ideal experimental design should isolate baseline trials from possible carry-over effects from irrelevant information and, at the same time, control other factors (e.g., stimulus uncertainty) that might affect RT.

To summarize, we have identified the reason for the conflicting evidence from our previous studies concerned with the facilitation and/or interference effects of an irrelevant directional cue. In the final analysis, however, we are unable to provide an authoritative answer to the broader question of whether irrelevant information can facilitate the processing of relevant information in a choice RT task. The answer must await a satisfactory solution to the problem of establishing an appropriate baseline RT.

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