Effect of the amount of the irrelevant disparity on different reaction times

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The effects of the amount of the irrelevant disparity on RTs in the *different* trials were examined. In the experiment, six subjects (undergraduate students) were instructed to report *same* or *different* according to a relevant dimension, trying to ignore an irrelevant dimension. There were six task-conditions to each of which one of six possible combinations of one relevant and one irrelevant dimensions selected from form, size, and orientation were allocated. It was found that in the combination of size and orientation, RTs in *different* trials decreased with the amount of the irrelevant disparity while in the other combinations, RTs in the *different* trials were not influenced by the amount of the irrelevant disparity. A two-stage model that had been suggested by Watanabe (1988) could well explain these results, according to which the degree of integrality between dimensions was one of the factors that determined RTs in the *different* trials.

Key words: irrelevant dimensions, relevant dimensions, *same-different* tasks, multidimensional stimuli, two-stage model, degree of integrality.

One of the most common issues in the *same-different* task is to attend to a relevant dimension while ignoring an irrelevant dimension in the *multi-dimensional stimuli*.

Egeth (1966) found that *S* RTs² were longer when the stimuli differed on irrelevant dimensions than when they were the same on all dimensions. This result led him to the conclusion that subjects could not ignore all of the irrelevant dimensions. Further, Dixon and Just (1978) found that the monotonous increase of *S* RTs with the amount of disparity in the irrelevant dimension in the combinations of (a) height in ellipse pairs as relevant and width as irrelevant, (b) width in ellipse as relevant and height as irrelevant, and (c) hue of color patches as relevant and tint as irrelevant. The same results have been obtained also in other dimensional combina-

tions; form and orientation (e.g. Shepard & Metzler, 1971), form and size (Besner & Coltheart, 1976; Bundesen & Larsen, 1975; Larsen & Bundesen, 1978), as relevant and irrelevant dimensions, respectively.

However, it is unfortunate that unlike *S* responses, *D* responses have not shown a systematic increase in RTs with increasing disparity in many of experiments (e.g., Besner & Coltheart, 1976; Carpenter & Just, 1978; Dixon & Just, 1978; Just & Carpenter, 1976; Santee & Egeth, 1980; Shepard & Metzler, 1971). In addition, Williams (1974) and Watanabe (1988) found that *D* RTs were shorter than *S* RTs when form was used as relevant and color as irrelevant.

These variations of the effects on *D* RTs with the irrelevant disparity have not been explained so successfully. The present study is, therefore, to clarify the mechanism that causes such different effects.

Recently, Watanabe (1988) examined the effects of the irrelevant dimensions in the *same-different* task in terms of their presence or absence. He found that all the results obtained in various dimensional combinations could be classified into three

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² *S* RTs mean the reaction times in the correct *same* responses while *D* RTs mean the reaction times in the correct *different* responses.

types of effects on D trials, as far as the dimensional combinations used as relevant and irrelevant have any interactional relations. The three types were (1) $RT(DS) > RT(DD)$, (2) $RT(DS) = RT(DD)$, (3) $RT(DS) < RT(DD)$, where the first and second members of each pair refer to the states of the relevant and irrelevant dimensions, respectively. In addition, Watanabe (1988) also found that these three types were determined by the degree of *integrality* (the degree of strength of the functional interaction) between the relevant and irrelevant dimensions, by means of the restricted classification task that had been established by Handel and Imai (1978). That is, the classification of the three different types is dependent on the degrees of the integrality of the dimensional combinations. On the basis of these findings, he suggested a two-stage model consisting of the preattentive stage that occurred early in the information processing and the second stage. At the preattentive stage, a comparison mechanism detects any piece of information indicating differences, whether it is relevant or irrelevant. The purpose of the preattentive stage is only to know whether any difference exists or not. As soon as the comparison mechanism finds any one of the differences, the processing will move into the next stage, without any further processing at the preattentive stage. Therefore, the larger the number of dimensions indicating difference is, the sooner the comparison mechanism will determine whether any difference is relevant or not. At the preattentive stage, it should be noted, the comparison mechanism does not know which dimensions are different (Miller, 1978). In this sense, this stage may be called preattentive.

At the second stage, the comparison mechanism must look for each of all the dimensions indicating difference and recheck its relevance. If there are two differences and one of them is relevant and another irrelevant, then the higher

the degree of integrality between the relevant and irrelevant dimensions, the more difficult it would be, and therefore, the longer time it would take, to recheck their relevances serially.³ Thus the processing time at this stage would be determined by the degree of the integrality between the relevant and irrelevant dimensions as well as the number of the detected differences.

This model can predict the three types of the effects in D RTs according to the degree of integrality between the relevant and irrelevant dimensions.

The processing time at the preattentive stage would be shorter in DD pairs than DS pairs by a certain amount of time ($\Delta t1$), since the comparison mechanism can find any one of differences faster as the number of differences increases. The processing time at the second stage to recheck the relevance, in contrast, would be longer in DD pairs than DS pairs (by $\Delta t2$), since differences should be rechecked serially. Therefore, it is expected that $RT(DD) - RT(DS) = \Delta t2 - \Delta t1$. $\Delta t1$ is constant for any combination between the relevant and irrelevant dimensions, because the salience of irrelevant dimensions involved was adjusted to be almost identical in the experiment on whose results the model was built; whereas $\Delta t2$ would be varied as the degree of their integrality increases, because it is more difficult to isolate them with the increasing degree of their integrality. That is why, the three types obtained in D responses; $RT(DD) < RT(DS)$, $RT(DD) = RT(DS)$, and $RT(DD) > RT(DS)$ can be predicted by the degree of integrality.

This model was built on the experimental situation in which steps of the irrelevant dimensional disparity within a pair of the stimulus was two (presence or absence of disparity) and, as mentioned above, the amounts of disparities in all the combinations of the relevant and irrelevant dimen-

³ Serial processing was suggested, because no interaction in RTs and errors was found between two irrelevant dimensions (Watanabe, 1988).

sions, if present, had been adjusted so that the salience of irrelevant difference looked identical to the subjects. The present study, however, is concerned with the effects of the amount of the irrelevant difference on *D* RTs, rather than effects of the presence or absence of the irrelevant disparity. We should deal with the case in which the disparity on the irrelevant dimension is varied with more than two steps.

What this two-stage model⁴ predicts in *D* RTs with the amount of disparity in the irrelevant dimensions in various combinations of the relevant and irrelevant dimensions? The comparison mechanism at the preattentive stage can detect any one of differences more easily as the amount of disparity in the irrelevant dimensions becomes larger. The processing time at the preattentive stage (*PT1*) will be shorter with the amount of disparity.

As told above, the relevance of the detected difference should be rechecked at the second stage.

Garner (1974) and Handel and Imai (1972) suggested that the amount of disparity (discriminability) was the feature that determined its salience only with dimensional combinations whose degree of integrality was high, not with those whose degree of integrality was low.

In the case that the degree of integrality between the relevant and irrelevant dimensions is high, therefore, the difference in the irrelevant dimension will be more salient as the amount of the irrelevant disparity becomes larger. That is why, the larger the amount of irrelevant disparity, the more difficult it is to separate irrelevant dimension from the relevant dimen-

sion. Therefore, with the dimensional combination whose degree of integrality is high, the processing time at the second stage (*PT2*) will be longer with the amount of the irrelevant disparity.

In the case that the degree of integrality between the relevant and irrelevant dimensions is low, the rechecking process in each dimension will occur independently. Therefore, *PT2* will not change over the amount of disparity in the irrelevant dimension.

The two-stage model predicts two types of effects of the amount of the irrelevant disparity on *D* RTs. In the case of the dimensions not being perfectly separable,⁵ RTs will be determined by *PT1*+*PT2*. With dimensions whose degree of integrality is high, on the one hand, *D* RTs may show slight increase or decrease with the increasing irrelevant disparity, but it will not be a drastic change, because *PT1* will decrease while *PT2* will increase, with the increasing irrelevant disparity. RTs with dimensions whose degree of integrality is low (but not to the level of zero), on the other hand, will be shorter as the amount of the disparity becomes larger, because *PT1* will decrease while *PT2* will not change with the increasing irrelevant disparity and, therefore, the decreasing tendency will appear in RTs.

Watanabe (1988) found that the degree of integrality is low in size and orientation; whereas the degree of integrality is high in the combination of form and size and the combination of form and orientation. In this experiment, it will be examined whether the two-stage model is adequate, using three dimensional combinations; size and orientation, form and size, and form and orientation. If the two-stage model is adequate, we can predict as follows:

1. Size and orientation:

⁴ In the case that the dimensions whose relation is perfectly separable are included in the involved dimensional combinations, the filtering out of the irrelevant dimensions would occur at the earliest stage and the three-stage model should be assumed (Watanabe, 1988). However, in order not to make the theory complex, such dimensions was not used in this study.

⁵ If the dimensions are perfectly separable, any effect of the irrelevant disparity cannot be expected.

D RTs will decrease with the amount of the irrelevant disparity.

2. Form and size, form and orientation:

D RTs will not change drastically with the amount of the irrelevant disparity.

Method

Subjects. Six undergraduate students, five males and one female, with ages ranging between 21 and 24 participated as subjects. All of them were right-handed, with normal color vision and normal or corrected-to-normal acuity.

Apparatus. A four-channel Ralph Gerbrands tachistoscope was used, but only three channels were utilized in this experiment. The viewing distance was 80 cm.

Stimulus materials. Two different channels of the tachistoscope were used for presenting a pair of stimuli. The stimuli were illuminated from back-light boxes attached to the channels. In this situation, 1 cm on the stimulus field subtended 0.72° in visual angle. One of the pair was presented 3.1 cm (2.2° in visual angle) left to the center of the stimulus field. Another was in the symmetrical position on the right side. The stimuli were produced by the black cards each of which was cut in a certain form, size, and orientation. For each task-condition, two identical sets of nine stimuli varied in three values with respect to two of the three dimensions: form, size, and orientation. The form was square, the relatively fat rectangle (height: width=2: 1), or the more attenuate rectangle (height: width=4: 1). The amounts of the form disparity between the square and the fat rectangle and between the attenuate rectangle and the fat rectangle were defined as one step. The amount of the form disparity between square and the attenuate rectangle were defined as two steps. The orientation was upright, tilted 22.5° , or tilted 45° . The size was small (1 cm^2), medium (2 cm^2), or large (4 cm^2). In each task-condition,

one of two dimensions with respect to which the stimuli varied was assigned to be relevant and another was to be irrelevant.

Procedure. There were six task-conditions in this experiment. In each task-condition, there were 81 trials in which all possible combinations of two sets of nine stimuli were presented. Each of six combinations of the relevant and irrelevant dimensions is allocated to each task-condition: Form / size, size / form, form / orientation, orientation / form, size / orientation, and orientation / size, where the first member of each combination represents the relevant dimension and the second the irrelevant dimension. In the restricted classification task conducted preliminarily, these combinations of the relevant and irrelevant dimensions had been found not to be perfectly separable dimensions. The six task-conditions were administered in a different order for each subject. One experimental session of approximately 60 min was assigned to each of the six task-conditions that consisted of 81 pairs of stimuli.

In each trial, a small white dot (3 mm in a diameter) was presented at the center of the stimulus field for 400 ms and followed by a pair of stimuli that were presented simultaneously for 50 ms. Subjects were asked to fixate the small white dot while it was presented. Then they were to report *same* or *different* as quickly as possible to a microphone, when a pair of the test stimuli were presented. Which was the relevant dimension had been told before the start of the first session of each task-condition. RTs were measured by means of the voice key that was connected to a microphone.

Results

In Fig. 1, the mean RTs of *D* responses as a function of irrelevant disparity, and the corresponding error rates were shown.

For each task-condition, correct *D* responses were subjected to a one-way

analysis of variance (disparity in the irrelevant dimension) with repeated measurements. Error responses were treated as missing values.

Of all the combinations, only in orientation / size the effect of disparity in the irrelevant dimension was significant [$F(2, 5)=6.41, p<.05$]. Then, the goodness-of-fit tests for upward and downward linear trends were further applied to *D* responses

only in orientation / size combination. The goodness-of-fit test for downward linear trend was significant [$p=.02$].

Discussion

In the size / orientation, *D* RTs decreased linearly with the amount of the disparity on orientation. In the other combinations of the relevant and irrele-

Fig. 1. Mean *D* RTs for correct responses in the upper part and mean percentages for error for *D* trials as a function of the irrelevant disparity in each of six conditions.

vant dimensions, *D* RTs were not found to be significantly affected by the amount of the irrelevant disparities. Remember the prediction of the two stage model. In the combination of size and orientation, whether in size / orientation or orientation / size, *D* RTs should decrease with the amount of the irrelevant disparities. In the combination of form and size and the combination of form and orientation, *D* RTs should not be affected by the amount of the irrelevant disparity. The prediction fits the results in five of six combinations. The result obtained in size / orientation seems to be at variance with the prediction. As shown in Fig. 1, however, the tendency is found that *D* RTs decrease with the amount of the irrelevant disparity in size / orientation, although not significantly. Therefore, it may well be said that the two-stage model successfully predicts effects of the amount of the irrelevant disparity on *D* RTs, at least in the combinations chosen from form, size, and orientation.

Several other models have been proposed to explain the effect of the amount of the irrelevant disparity on RTs.

One of them is a *normalization model*, which postulates an analog process that equates two stimuli in the irrelevant dimension before deciding whether they are identical on the relevant dimension or not (Dixon & Just, 1978). This model predicts that *D* RTs increase monotonously with the amount of disparity within a pair of stimuli on the irrelevant dimension.

The other is a *response competition model*, which assumes that the relevant and irrelevant dimensions are processed by separate dimensional analyzers. If the output (*S* or *D*) of the relevant analyzer is not identical to that of the irrelevant analyzer, RTs will raise because of the competition between the relevant and irrelevant analyzer at the response level. This model predicts the monotonous decrease of *D* RTs with the amount of the irrelevant disparity, because a difference in the irrelevant

dimension is compatible with the required *D* responses and, therefore, makes subjects release *D* responses more easily.

Any of the experimental results obtained in the present study is not in accordance with what the normalization model predicts as far as *D* responses are concerned. On the other hand, what the response competition model predicts seems to suit the result obtained in size / orientation. However, it does not suit the results obtained in the other combinations. These two models cannot explain both of two types of results obtained here.

Summary

To summarise the present study, two different types were found in the effects of the amount of the disparity on *D* RTs. 1. In the combination of size and orientation, *D* RTs decreased with the amount of the irrelevant disparity. 2. In the combination of form and size and the combination of form and orientation, *D* RTs was constant over the amount of the irrelevant disparity. The degree of integrality had been found to be low in the combination of size and orientation; whereas it had been found to be high in the combination of form and size and the combination of form and orientation. Therefore, these results can be explained successfully by the two-stage model (Watanabe, 1988) including the processing in which the variation of the effects is dependent upon the degree of integrality between relevant and irrelevant dimensions.

References

- Besner, D., & Coltheart, M. 1976 Mental size scaling examined. *Memory & Cognition*, **4**, 525-531.
- Bundesen, C., & Larsen, A. 1975 Visual transformation of size. *Journal of Experimental Psychology: Human Perception and Performance*, **1**, 214-220.
- Carpenter, P. A., & Just, M. A. 1978 Eye fixa-

- tions during mental rotation. In J. W. Senders, D. F. Fisher & R. A. Monty (Eds.), *Eye movements and the higher psychological functions*. Hillsdale, N. J.: Lawrence Erlbaum Associates. Pp. 115-133.
- Dixon, P., & Just, M. A. 1978 Normalization of irrelevant dimensions in stimulus comparisons. *Journal of Experimental Psychology: Human Perception and Performance*, **4**, 36-46.
- Egeth, H. E. 1966 Parallel versus serial processes in multidimensional discrimination. *Perception & Psychophysics*, **1**, 245-252.
- Garner, W. R. 1974 *The processing information and structure*. Potomac, Md.: Erlbaum.
- Handel, S., & Imai, S. 1972 The free classification of analyzable stimuli. *Perception & Psychophysics*, **12**, 108-116.
- Just, M. A., & Carpenter, P. A. 1976 Eye fixations and cognitive processes. *Cognitive Psychology*, **8**, 441-480.
- Larsen, A., & Bundesen, C. 1978 Size scaling in visual pattern recognition. *Journal of Experimental Psychology: Human Perception & Performance*, **4**, 1-20.
- Miller, J. 1978 Multidimensional *same-different* judgments: Evidence against independent comparisons of dimensions. *Journal of Experimental Psychology: Human Perception and Performance*, **4**, 411-422.
- Santee, J. L., & Egeth, H. E. 1980 Selective attention in the speeded classification and comparison of multidimensional stimuli. *Perception & Psychophysics*, **28**, 191-204.
- Shepard, R., & Metzler, J. 1971 Mental rotation of three-dimensional objects. *Science*, **171**, 701-703.
- Watanabe, T. 1988 Effects of irrelevant differences as a function of the relations between relevant and irrelevant dimensions in the *same-different* task. *Journal of Experimental Psychology: Human Perception and Performance*, **14** 132-142.
- Williams, C. 1974 The effect of an irrelevant dimension on "same"- "different" judgments of multidimensional stimuli. *Quarterly Journal of Experimental Psychology*, **26**, 26-31.

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