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A NOTE ON INFORMATION PROCESSING IN CROSS-MODAL MATCHING

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Garvill, J., and Molander, B. A note on information processing in cross-modal matching. Umeå Psychological Reports No. 95, 1975. - Intra-modal and cross-modal matching of form was studied. The hypothesis that differences in accuracy between modality conditions found in earlier experiments were due to differences in rate of information pick-up between the visual and tactual modalities was tested. The modality conditions were visual standard or tactual standard and visual comparison or tactual comparison. The subjects made paired comparisons of three-dimensional "nonsense" objects and were allowed to inspect the stimuli for as long as they wanted. The time was measured for the standard object and the comparison object. It was found that the visual modality had a higher rate of information pick-up than the tactual modality. However, the differences in accuracy between the modality conditions were not eliminated despite the differences in presentation time. Other possible explanations of the differences in accuracy are discussed.

This study is concerned with subjects' ability to match objects presented in different modalities. Specifically, we are concerned with their ability to match objects presented visually to objects presented tactually, and vice versa. In an earlier experiment in this series (Garvill & Molander, 1973), we found that the effects of modality for comparisons involving identical objects differed from those for comparisons involving different objects. When the two objects were identical, visual presentation of the stimuli led to higher accuracy, but the effect of the modality for the standard object was more powerful than that of the modality of the comparison object. For comparisons involving different objects, there was an interaction between the modality of the comparison object and that of the standard object. Accuracy was highest when both objects were presented visually, but there were no differences among

remaining three comparisons: (1) both objects presented tactually, (2) standard presented visually, comparison tactually, and (3) standard presented tactually, comparison presented tactually. Similar results have been obtained by Koen (1971).

The results with respect to the effects of modality were interpreted as an indication that the visual mode has greater information processing capacity than the tactual mode. That is, the visual mode picks up more information per unit time than does the tactual mode. The superiority of the visual mode has been established in many studies e.g. Cashdan and Zung (1970), Björkman (1971), Fico and Brodsky (1972), Walsh (1973), Bryant and Raz (1975).

The differences between the two kinds of comparisons, viz., comparison of identical objects and comparison of different objects, on the other hand, may be due to the fact that it is harder to establish that two objects are identical than that they are different. In the former case, the subjects have to compare the objects in every single respect before a decision is made. In the latter case, it is sufficient to find that the objects differ in one respect and as soon as a mismatch is found the decision can be made. Thus, more information is required for deciding that objects are identical than for deciding that they are different. Consequently, we would expect that the effects of the differences in information processing capacity between the two modalities would be more pronounced for comparisons involving identical objects than for comparisons involving different objects. This hypothesis has also been suggested by Birch and Lefford (1963).

The present experiment was designed to test the hypothesis that the results described above can be explained in terms of rate of information pick-up. In earlier experiments on intra-modal and cross-modal matching, the standard and comparison stimuli have been presented for fixed periods of time, and the duration has frequently been the same regardless of modality or type of comparison. If there are differences between modalities with respect to rate of information pick-up, and if different comparisons require different amounts of information, such a procedure would

lead to more errors for comparisons involving tactual presentation than for comparisons involving visual presentation, and to more errors for comparisons involving identical objects than for comparisons involving different objects. In the present experiment, on the other hand, the subjects were allowed to inspect the stimuli for as long as they wanted. Thus, they could compensate for differences in rate of information pick-up by inspecting the stimuli for a longer period of time when they were presented tactually and for comparisons requiring more information. The hypothesis that earlier results are due to differences in rate of information pick-up predicts that in this experiment there will be no differences between modalities or between types of comparisons with respect to errors. There will however, be differences with respect to inspection time, paralleling those with respect to errors in earlier experiments.

Method

Subjects. Forty undergraduate psychology students from the University of Umeå served as subjects to fulfill a course requirement. The subjects were randomly assigned to four groups of ten subjects each.

Design. The independent variables studied in this experiment were standard modality V or T (visual or tactual presentation of the standard object), comparison modality V or T (visual or tactual presentation of the comparison object) and kind of comparison (comparison of identical objects or comparison of different objects). The dependent variables were time spent on standard object and on comparison object and number of errors. False negatives FN-errors, (the subject responds "different" when the objects are in fact identical) and false positives FP-errors, (the subject responds "same" when the objects are in fact different) were analyzed separately.

Stimuli. The stimuli were five three-dimensional "nonsense" ceramic objects of the same kind as those used by Gibson (1962). They were all painted white, and were all of the same weight. Thus they differed only in form. A drawing of one of the stimuli as well as of the experimental setting is provided in Garvill and Molander (1971).

Apparatus. During the experiment the subject was seated in front of a screen. When an object was presented in the tactual modality the subject put his hands under the screen and could then explore the object without seeing it. During the visual presentations the objects were placed in the middle or a rotating disc behind the screen and at the same level as the upper edge of the screen (eye-level). The rate of rotation was one turn per five sec.

Procedure. Every subject made 80 comparisons. Each object appeared 16 times as standard object in a randomized order. On eight occasions it was paired with itself as comparison object and the other eight occasions it was paired with one of the remaining objects, each object serving as comparison on two occasions. Thus the subjects made 40 comparisons of identical objects and 40 comparisons of different objects, and they were required to respond "same" or "different" for each comparison. They were not told whether their answer was correct or not. The standard was always presented first and the time was measured until the subject indicated that he was satisfied after which the standard was removed. After a five sec. interval the comparison was presented and the time measured until the subject responded "same" or "different". The inter-trial interval was five sec.

Results

Errors. The errors were divided into FN-errors (false negatives) and FP-errors (false positives). Since the error distributions were skewed the individual error scores were transformed according to the formula log (number of errors + 1) as suggested by Winer (1962). The FN- and FP-errors were then analyzed separately.

The transformed FN-errors were subjected to a two-way analysis of variance with standard modality (V or T) and comparison modality (V or T) as factors. The analysis yielded a significant main effect of standard modality ($F = 16.17$, $df = 1/36$, $p < .01$) which was due to the fact that visual standard resulted in less errors than tactual standard, see Table 1. No other effects were significant. The transformed FP-errors were ana-

Table 1. Mean number of transformed errors for the four modality conditions.

Modality condition	FN-errors	FP-errors
VV	.14	.04
VT	.18	.12
TV	.35	.17
TT	.33	.05

lyzed in the same way as the FN-errors. The only significant effect was an interaction effect between standard modality and comparison modality ($F = 9.60$, $df = 1/36$, $p < .01$). The interaction was further analyzed by means of Newman-Keuls' method for comparisons among treatment means. The analysis showed that there was no difference between the two intramodal conditions (VV and TT) or between the two cross-modal conditions (VT or TV) but that the intra-modal differed significantly from the cross-modal conditions ($p < .01$) with intra-modal matching resulting in less errors than cross-modal matching, see Fig. 1.

To assess the relative difficulty of the two kinds of comparisons (comparison of identical objects and comparison of different objects) the number of errors for each task was compared within each modality condition. There were significantly more errors for comparisons of identical objects than for comparisons of different objects in the VV, TV and TT conditions (Students t-test for correlated observations, $p < .05$). In the VT condition the difference was in the same direction but did not reach significance.

The different patterns of errors in this experiment are generally congruent with the results obtained in our earlier experiment (Garvill & Molander, 1973).

Time. The median times were calculated for each individual for the standard and for the two kinds of comparison.

The median times for the standard were analyzed in a two-way analysis of variance with standard modality (V or T) and comparison modality (V or T) as factors. The results showed that visual presentation of the standard resulted in shorter times than tactual presentation ($F = 85.72$, $df = 1/36$, $p < .01$).

Separate analyses were performed for comparisons involving identical stimuli and for comparisons involving different stimuli. For both kinds of comparisons, visual comparison was faster than tactual comparison ($F = 34.34$, $df = 1/36$, $p < .01$, for identical objects and $F = 93.85$, $df = 1/36$, $p < .01$ for different objects) Comparison after visual standard was faster than comparison after tactual standard (F 4.64, $df = 1/36$, $p < .05$ for identical objects and $F = 6.85$, $df = 1/36$, $p < .01$ for different objects). The results are shown in Table 2.

Table 2. Median times for the standard object, for comparison involving identical objects and for comparison involving different objects for the four modality conditions in sec.

Modality condition	Standard object	Comparison of identical objects	Comparison of different objects
VV	5.18	3.83	1.22
VT	7.02	7.58	4.72
TV	17.07	4.47	2.29
TT	16.95	10.54	5.47

Finally, the time for comparison of identical objects and for comparison of different objects was compared within each modality condition. It was found that the time for comparison of identical objects was significantly longer in all conditions (Student's t-test for correlated observations, $p < .01$).

Discussion

The present results support the hypothesis that the visual modality has a higher rate of information pick-up than the tactual modality in that we find that the subjects used much more time for tactual stimuli than for visual stimuli, as well as the hypothesis that comparison of identical objects requires more time than comparison of different objects. However, despite the fact that the subjects were allowed to use as much time as they wanted for their inspection of the stimuli, they did not achieve perfect accuracy, and the pattern of errors in this experiment is congruent with that in earlier experiments. Consequently, the results in earlier experiments cannot be explained in terms of rate of information pick-up only. Other factors have to be considered as well.

One hypothesis advanced by Posner (1967) and elaborated by Goodnow (1971) states that visual and tactual information is stored in different memories and that the memory for tactual information is less stable than the memory for visual information. This hypothesis has not recieved support in experiments where the length of the retention interval between the standard and the comparison have been varied (Garvill & Molander, 1973; Abravanel, 1973), and some results in this experiment suggest another explanation. In the analysis of time for comparison an effect of standard modality was found, in addition to the effect of comparison modality. When the information about the standard was acquired visually the subjects used less time for comparison then when the standard was presented tactually, given the same comparison modality. This suggests that the visually and tactually acquired information may differ in organisation or availability.

This experiment also indicated that the accuracy in intra-modal and cross-modal matching is very much dependent upon the complexity, or difficulty, of the matching task. If the task requires complex information, as does the identification task, the input modality is the important factor. In this case the visual modality is superior to the tactual modality. However, if the task requires less complex information as does the discrimination task, the tactual modality, given

enough time, might lead to the same level of performance as the visual modality. In this case accuracy is dependent, not upon modality per se, but upon whether the information has to be translated from one modality into another or not.

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