F. 118

5.

UMEÅ PSYCHOLOGICAL REPORTS

No. 125 1977

Department of Psychology

University of Umeå

S-901 87 Umeå/SWEDEN

THE INVARIANCE OF ASYMMETRIC CROSS-MODAL TRANSFER EFFECTS

Bo Molander

Jörgen Garvill

THE INVARIANCE OF ASYMMETRIC CROSS-MODAL TRANSFER EFFECTS

Molander, B., and Garvill, J. The invariance of asymmetric cross-modal transfer effects. Umeå Psychological Reports No. 125, 1977. - In two experiments cross-modal transfer as a function of amount of first modality training was investigated. Subjects learned to associate numbers with three-dimensional objects which were presented either visually or tactually. After training in one of the modalities transfer was tested in the other modality. In the first experiment the transfer test was conducted after 4, 8, 12, 18, or 36 trials of training and in the second experiment it was conducted after learning 100 %, 150 %, or 200 %. Transfer in the tactual-visual order was superior to transfer in the visual-tactual order in all training conditions, and the magnitude of the effect was the same. The results suggest that learning factors are of minor importance as causes to the asymmetry between modalities and that it is more fruitful to concentrate on perceptual factors.

Studies of cross-modal transfer and matching have generally shown that the sense modalities differ in their capacity to handle different kinds of information and that the size of the transfer effect from one modality to another varies with modality order (Freides, 1974). In the learning of forms in the visual and tactual modalities most studies show that visual learning is superior to tactual learning. In contrast, the results with respect to cross-modal transfer in experiments using forms as stimuli are confusing. Some authors (Gaydos, 1956; Björkman, Garvill & Molander, 1965; Eastman, 1967; Garvill & Molander, 1968; 1971; Cashdan, 1968; and Koen, 1971) have reported that transfer is superior for the tactual - visual order. Others (Lobb, 1965; Cashdan 1968; Fico & Brodsky, 1972; Walsh, 1973) have found the opposite effect, and still others (Walk, 1965; Krauthamer, 1968; Clark, Warm, & Schumsky, 1972; Zung, Butter & Cashdan, 1974) have found no differences.

It has been suggested that differences in learning capacity for the visual and tactual modalities may explain the transfer effects. In his review of cross-modal studies (1970), von Wright noted that if a learning task was harder to learn in one modality than the other, there was more transfer from this modality to the easier modality, than vice versa. When the learning task was equally difficult in both modalities, symmetric transfer effects were obtained. These results would agree with those found in verbal learning (Battig, 1966) which show more transfer from a hard task to an easy task. There are exceptions to this pattern, however. Lobb (1970), for instance, made a form discrimination equal in difficulty in the visual and tactual modalities and tested for transfer. Cross-modal effects occurred only in the visual-tactual direction. In discussing these results the author suggested that increased training in the first modality may give more symmetrical effects.

In two earlier studies (Björkman, et al., 1965; Björkman, 1969) the transfer effect was invariant over two different levels of learning (e.g., .70 and 1.00). On both levels transfer in the tactual-visual order was about 60 % and in the visual-tactual order about 40 %. The magnitude of the asymmetric effect then, seems to be independent of level of learning. However, in order to reach the learning criteria tactual training required approximately twice as many trials as visual training. It is possible then that this difference in number of trials and thus also in the time stimuli are exposed to the subjects, may explain the asymmetry. In the first experiment presented below, this possibility is investigated. Visual and tactual groups are given the same number of training trials before transfer is tested in the other modality. The number of trials varies from 4 to 36 to cover the range from a low level of training to an high level of training.

The purpose of the second experiment is to follow Lobb's (1970) suggestion as stated above and investigate the effect of overlearning on the asymmetry more systematically. Presumably the difference in the difficulty of handling forms in the visual and tactual modalities will be reduced with increased training. Different groups are trained in either the visual or the tactual modality and carried to a criterion of 100 %, 150 %, or 200 % learning, where upon transfer is tested in the other modality.

Experiment 1

Method

Subjects. 100 male and female students from introductory courses in psychology at the university of Umeå served as subjects. Participation in the experiment was part of a course requirement and the subjects had no earlier experience of cross-modal experiments.

Material. Seven ceramic objects were used as stimuli. These stimuli are similar to the ones originally designed by Gibson (1963) and have different "nonsense" shapes. Otherwise they are identical in smoothness, color, size and weight. In the present case the objects were painted white, the height and weight being approximately 10 cm and 350 gr respectively. Each of the objects could easily be grasped by one hand although the subject was instructed to use both hands in the tactual training. A drawing of one of the stimulus objects as it is presented in the experimental situation is provided elsewhere (Garvill & Molander, 1971). To each of the seven objects a number between 1 and 7 was randomly assigned. These numbers constituted the responses and since there was no inherent relation between the stimulus properties and the numbers the subjects had to learn to which object each number belonged by rote.

Apparatus and procedure. The subjects were randomly assigned to 10 groups with 10 subjects in each. In five of the groups training started in the tactual modality whereupon transfer was tested in the visual modality (TV). The other five groups were trained and tested in the opposite order (VT). In each modality order the transfer test occurred after 4, 8, 12, 18, or 36 trials of training in the first modality. Consequently a 2 (modality order) x 5 (number of trials) factorial design was formed. During the experiment the subject was seated in front of a screen. When a stimulus object was presented tactually the subject put his hands under the screen and could then manipulate the object by active touch without seeing it. During visual presentation

the stimulus object was placed on a rotating disc behind the screen and at the same level as the upper edge of the screen (eye level). The rate of rotation of the disc was two turns during the exposure which lasted for 10 seconds. The exposure time was the same in visual and tactual conditions. At the end of each exposure the assigned number was presented by means of a tape recorder. Since the training followed a PA-learning procedure the subject thus had to respond within 10 seconds after the stimulus presentation and before feedback was given from the tape recorder. Before the start of the training phase the subject read standard instructions where the anticipation method was explained and where it was pointed out that on the first trial he had to guess the correct numbers. No information was given about the learning criterion in the training phase or that training was followed by a transfer phase in another modality. Before the training started a demonstration of the procedure was made by presenting the subject a stimulus-response pair which did not belong to the experimental pairs. After training was completed in the first modality and before transfer was tested in the second modality there was a pause on approximately 1 minute where the apparatus was changed and where new instructions were given to the subject. He was informed that the training would go on exactly as in the first phase with the same stimuli and responses with the exception that stimuli would be presented in another modality. From the very first trial in the transfer phase the subject thus was supposed to give as many correct responses as possible and if he did not know the correct response he had to guess. The training in the transfer phase was carried to a criterion of two consecutive correct trials. The interitem interval as well as the intertrial interval was 5 seconds and to prevent serial learning, the order of stimulus presentation was varied from trial to trial. Each subject spent approximately one hour and a half in the laboratory.

Results

In each of the ten groups the proportion correct responses in the last trial in the training phase was calculated. A two-way analysis of variance on this measure showed that the visual modality was superior to the tactual modality ($F(1.90) = 36.97, p < .01$), visual learning being approximately twice as effective as tactual learning. Not surprisingly

there was also a significant effect of number of trials, ($F(4.90) = 57.76$, $p < .01$), and a significant modality $\times$ trials interaction ($F(4.90) = 6.62$, $p < .01$), the latter effect of course indicating that the difference between modalities decreased with increased training. After 4 trials of training the proportion correct responses was .18 in the tactual condition and .31 in the visual condition. (The proportion correct responses for all conditions can be seen in Figure 1.) After 36 trials the corresponding values were .96 and 1.00, where the latter figure is an expression of some overlearning since the asymptote was reached after 12 trials. Thus the variation in number of trials covered a substantial range of levels of learning.

In earlier studies using the present paradigm (Björkman, et al., 1965; Garvill & Molander, 1968) transfer has been calculated according to the formula $(P_1 - p_1)/(p_k - p_1)$ where P_1 is the proportion correct responses in the first trial in the transfer phase, p_k the proportion correct responses in the last trial in the training phase and p_1 the proportion responses correctly guessed in the first trial in the training phase. Unfortunately this formula tends to give anomalous values on low levels of learning since for some subjects p_1 may be equal to or larger than p_k or P_1 may be larger than p_k . Thus, in the present case transfer was calculated as the proportion P_1/p_k but with the restriction that 1.00 was substituted for values exceeding unity. A two-way analysis of variance performed on this measure yielded a significant effect of modality order ($F(1.90) = 4.05$, $p < .05$) indicating that comparatively more correct responses were given after tactual training than after visual training. The mean proportion transfer and standard deviations after different amounts of training are presented in Table 1.

Table 1. Mean proportion transfer (P_1/p_k) and standard deviations after different amounts of training in the first modality.

Modality order		TRIALS				
		4	8	12	18	36
T-V	Mean	.90	.82	.87	.73	.77
	S D	.32	.25	.19	.23	.20
V-T	Mean	.76	.73	.69	.75	.67
	S D	.37	.18	.21	.15	.23

No other effects were obtained in the analysis ($F < 1$). The results show then that the asymmetric effect remains when the stimuli are exposed the same number of times in the two modalities. Furthermore, the size of the asymmetric effect seems to be independent of amount of training.

The data obtained from the present experiment makes it possible to get an impression of the rates of tactual and visual learning as well as the simultaneously ongoing cross-modal learning. Learning curves can be seen in Figure 1 where the proportion correct responses in the last training trial and the proportion correct responses in the first transfer trial have been plotted for all T-V and V-T conditions.

As can be seen in Figure 1 visual learning reaches the asymptote after 12 trials of training. The curve for tactual performance after visual learning reaches the asymptote after about the same amount of training, although this asymptote is on a lower level. This latter curve can be seen as an expression of the potential tactual information picked up during visual learning. Thus visual learning and the parallel tactual learning seem to have the same learning rates but different asymptotes. The same pattern can be seen in comparing the curve for tactual learning with the curve for visual performance after tactual learning, although acquisition is slower and stable asymptotic levels are still not reached after 36 trials of training. It should be noted

Fig. 1. Intra-modal and cross-modal performance as a function of amount of training.

too, that in terms of number of correct responses, there is more transfer from the visual modality to the tactual modality for low and moderate amounts of training. In relation to learning performance however, transfer from the tactual modality to the visual modality is superior over the whole range of training. Thus, it is evident that different conclusions may be drawn about the direction of the asymmetric effect, depending on what levels of learning are used or what measure of transfer is applied.

Experiment 2

Method

Subjects. 60 male and female students from introductory courses in psychology at the University of Umeå served as subjects. Participation in the experiment was part of a course requirement and no subjects had earlier experience of cross-modal experiments.

Material and apparatus. Same as in Experiment 1.

Procedure. The subjects were randomly assigned to 6 groups with 10 subjects in each group. In three of the groups the material was learned in the T-V order. After training in the tactual modality to a level of learning of 100 %, 150 %, or 200 %, transfer was tested in the visual modality. The remaining three groups proceeded in the reverse order. Thus a 2 (modality order: T-V vs. V-T) x 3 (levels of learning: 100 %, 150 %, 200 %) factorial design was formed. The criterion of 100 % learning was two consecutive correct trials and after the shift from the first modality to the second training proceeded to the same criterion. In order to get an indication of how the response strength changed during overtraining response latencies were measured in the two 200 % training groups. Time was measured by a stopwatch from the moment the stimulus object was placed in front of the subject until he responded. Information about the correct response was given 10 seconds after each stimulus presentation and in those cases where the subject

failed to respond within the proper interval his response latency was assigned a value of 10 seconds. In all other respects the procedure of Experiment 1 was followed. The total time each subject spent in the laboratory varied between 1 and 2 hours depending on training conditions.

Results

The number of trials to the criterion of 100 % learning was calculated for all groups. An analysis of variance performed on this measure showed as in the first experiment that visual learning is faster than tactual learning ($F(1.54) = 45.70$, $p < .01$), the mean number of trials for V-T groups being 11.8 and for T-V groups 21.6. Transfer was calculated in the same way as in Experiment 1 but since learning was carried to high levels no corrections had to be made. A two-way analysis of variance performed on the P_1/p_k measure showed that the transfer effect was significantly larger for T-V groups ($F(1.54) = 15.07$, $p < .01$), and that there were no effects of overlearning ($F < 1$). Means and standard deviations based on the P_1/p_k measure are presented in Table 2.

Table 2. Mean proportion transfer (P_1/p_k) and standard deviations at different levels of learning in the first modality.

Modality order	LEVELS OF LEARNING					
	100 %		150 %		200 %	
	M	S D	M	S D	M	S D
T-V	.83	.12	.92	.10	.85	.14
V-T	.66	.15	.68	.21	.81	.15

As can be seen in Table 2 T-V values are larger than V-T values and furthermore relatively constant over the different levels of learning. For the V-T values there is an increment in the 200 % learning condition compared to the two other conditions. This increment, however, is nonsignificant and a comparison with the results in experiment 1 indicates that the increment is adventitious. The mean number of trials to

reach the criterion of 200 % learning was 23.60 for the V-T group and the proportion transfer as given in Table 2 is .81. In Experiment 1, on the other hand, transfer after 36 trials of training for the V-T group was .67, that is about the same as in the first two conditions in Table 2. The degree of overlearning in the 36 trials of training group is substantial, the mean level of learning being 297 %.

The analysis of response latencies clearly indicates that the subjects are still learning even long after they have reached the asymptote in the first modality training. In the two 200 % training groups median response latencies for each subject was calculated in trials where the criterion of 100 %, 150 %, and 200 % training respectively were met. A 2 (modality order) x 3 (levels of learning) analysis of variance with repeated measures in the second factor performed on those data yielded a significant effect of modality ($F(1.18) = 54.74, p < .01$), the V-T group responding faster than the T-V group, and a significant effect of training ($F(2.36) = 8.60, p < .01$). No modality x training interaction was found. The mean proportion correct responses and mean response latencies for the different learning criteria are presented in Table 3.

Table 3. Mean proportion correct responses (p_k), mean response latencies (RT) and standard deviations at different levels of learning in the first modality.

Modality order		LEVELS OF LEARNING					
		100 %		150 %		200 %	
		M	S D	M	S D	M	S D
T-V	p_k	1.00	.00	.93	.18	.97	.09
	RT	4.7	.98	4.5	.88	4.0	.51
V-T	p_k	1.00	.00	.99	.04	.99	.04
	RT	3.1	.61	2.6	.34	2.5	.32

As can be seen in Table 3 the reaction times in both groups are decreasing during overlearning, the T-V group consistently slower. In fact, the T-V group is slower after 200 % training than the V-T group is after 100 % training. Although the response latencies are decreasing as a function of overlearning the difference between the two groups is maintained and it seems as if more than 200 % training is needed to bring the visual and tactual modality to the same level. Further information on this matter can be obtained from Figure 2 where response latencies from each of the criterion trials and the three trials proceeding them has been plotted. As this figure indicates both groups have actually reached stable levels before the criterion of 200 % learning has been met and judging from the trends of the curves it does not seem likely that further training would change those levels.

The response latency measure indicates not only "response strength" but also the time needed to scan and recognize the objects. The results as shown in Figure 2, suggest that there may be inherent differences in perceptual scanning capacity between the modalities and that these differences are relatively insensitive to learning. Results pointing in the same direction have been obtained by the present authors in a cross-modal matching situation where response latencies were measured (Garvill & Molander, 1975).

Discussion

In agreement with earlier reports where the same type of stimulus material have been used (Björkman, et al., 1965; Garvill & Molander, 1968; Garvill & Molander, 1971) the present experiments show that transfer in the tactual-visual order is superior to transfer in the visual-tactual order. The results of Experiment 1 indicate, that the asymmetry remains when stimuli are presented the same number of times in the two modalities. Furthermore, the size of the transfer effects is invariant over different amounts of training. However, one crucial point is if the size of the effects has changed in Experiment 1 in comparison with experiments where the criterion has been a certain level of learning. Although the invariance of the asymmetry in Ex-

Fig. 2. Mean response latencies at different levels of learning in the first modality.

periment 1 in itself indicates that this is not the case more direct comparisons can be made. The mean proportion transfer for T-V and V-T groups as based on the values in Table 1 are .82 and .72 respectively, and in an earlier reported experiment (Garvill & Molander, 1968) where the same material and paradigm was used but where first modality training in the two groups was carried to a level of learning criterion (80 %) corresponding values were .85 and .74. Approximately the same results are obtained in Experiment 2 in the present report, the means based on Table 2 being .87 and .72 for T-V and V-T respectively. Thus, the hypothesis that the asymmetric effect is caused by different number of stimulus presentations during tactual and visual training is not supported.

The present experiments also demonstrate that the asymmetric effect is independent of level of learning. The size of the effect is the same for different levels of learning, including substantial overlearning. Thus, the present results are in agreement with the findings reported earlier by Björkman, *et al.*, (1965) and Björkman (1969). Despite the fact that learning improved during the overlearning conditions as indicated by the decreasing response latencies, the size of the cross-modal effects did not change as a function of overlearning. In this respect the results are at variance with those from verbal learning studies where overlearning gives clear effects on retention (Postman, 1962)

Another finding from the verbal learning area that is of interest in the present case is that subjects during overlearning tend to pay attention to cues other than those utilized in earlier phases of the learning (James & Greeno, 1967; Richardson, 1972). From the design of Experiment 2 there is no possibility to conclude that attention shifts do not occur. It can be concluded however, that there is no shift between modality specific cues and cues common to the two modalities, since such a shift should change the size of the transfer effect.

The general impression given by the present results is that learning factors are of minor importance in cross-modal performance. Of course, the more training subject receives in a modality, the better the cross-modal performance in absolute terms. The relative size of the specific transfer effects, however, seems to be quite unaffected. The common practice to design cross-modal experiments as paired associate learning may thus be unfortunate since such studies tend to focus the interest on irrelevant variables and unwarranted analogies with verbal learning processes. As far as the asymmetric effect is concerned it would perhaps be more fruitful to concentrate on the perceptual aspects of the modalities rather than the learning aspects. The difficulty of making the tactual and visual modalities equal in response latency as indicated by Figure 2 suggests the possibility of inherent differences in perceptual scanning, and the fact that the direction and size of the asymmetry vary in different studies where different material is used also points to the importance of perceptual factors.

However, it should be pointed out that there still remain some possibilities to manipulate the size of the asymmetry, one such possibility being a more direct reinforcement of the cross-modal performance. In the present experiments the subjects were not explicitly instructed to attend to common cues and since there is only one shift between the modalities there is a minimum of reinforcement of the cross-modal performance per se. The subjects evidently do not automatically change their perceptual strategies in such a procedure but if there were repetitive shifts between modalities, e.g., an alternate study and recall procedure, cross-modal performance would presumably change with increased training.

The authors are grateful to Dr. B. Brehmer for valuable comments on drafts of the manuscript and to Miss I. Sundberg and Mr. G. Qvarnström for assistance in the experimental work. The investigation was supported by a grant from the Swedish Council for Social Science Research.

References

- Battig, W. F. Facilitation and interference. In Bilodeau, E. A. (Ed.), Acquisition of skill. New York: Academic Press, 1966.
- Björkman, M., Garvill, J., & Molander, B. Cross-modal transfer as a function of preparatory set and distinctiveness of stimulus aspects. Reports from the Psychological Laboratories. University of Stockholm, No. 186, 1965.
- Björkman, M. Cross-modal effects in human learning and judgment. Paper read at XIX International Congress of Psychology. London, 1969.
- Cashdan, S. Visual and haptic form discrimination under conditions of successive stimulation. Journal of Experimental Psychology, 1968, 76, 215-218.
- Clark, J. L., Warm, J. S., & Schumsky, D. A. General and specific factors in the intersensory transfer of form. Journal of Experimental Psychology, 1972, 95, 184-188.
- Eastman, R. Relative cross-modal transfer of a form discrimination. Psychonomic Science, 1967, 9, 197-198.
- Fico, J. M., & Brodsky, H. S. The effect of visual and tactual stimulation on learning of abstract forms. Psychonomic Science, 1972, 27, 246-248.
- Freides, D. Human information processing and sensory modality: Cross-modal functions, information complexity, memory, and deficit. Psychological Bulletin, 1974, 81, 284-310.
- Garvill, J., & Molander, B. Asymmetric effects in cross-modal transfer. Umeå Psychological Reports No. 3, 1968.
- Garvill, J., & Molander, B. Verbal mediation in cross-modal transfer. British Journal of Psychology, 1971, 62, 449-457.
- Garvill, J., & Molander, B. A note on information processing in cross-modal matching. Umeå Psychological Reports No. 95, 1975.
- Gaydos, H. F. Intersensory transfer in the discrimination of form. American Journal of Psychology, 1956, 69, 107-110.

- Gibson, J. J. The useful dimensions of sensitivity. American Psychologist, 1963, 18, 1-15.
- James, C. T., & Greeno, J. G. Stimulus selection at different stages of paired-associate learning. Journal of Experimental Psychology, 1967, 74, 75-83.
- Koen, F. Verbal mediators in cross-modal form discrimination. Canadian Journal of Psychology, 1971, 25, 103-110.
- Krauthamer, G. Form perception across sensory modalities. Neuropsychologia, 1968, 6, 105-113.
- Lobb, H. Vision versus touch in form discrimination. Canadian Journal of Psychology, 1965, 19, 175-187.
- Lobb, H. Asymmetrical transfer of form discrimination across sensory modalities in human adults. Journal of Experimental Psychology, 1970, 86, 350-354.
- Postman, L. Retention as a function of degree of overlearning. Science, 1963, 135, 666-667.
- Richardson, J. Stimulus selection in associative learning. In Duncan, C. P., Sechrest, L., and Melton, A. W. (Eds.), Human memory: Festschrift for Benton J. Underwood. New York: Appleton-Century-Crofts, 1972.
- Walk, R. D. Tactual and visual learning of forms differing in degree of symmetry. Psychonomic Science, 1965, 2, 93-94.
- Walsh, J. K. Effect of visual and tactual stimulation on learning abstract forms: A replication. Bulletin of the Psychonomic Society, 1973, 2, 357-359.
- von Wright, J. M. Cross-modal transfer and sensory equivalence - a review. Scandinavian Journal of Psychology, 1970, 11, 21-30.
- Zung, B. J., Butter, E. J., & Cashdan, S. Visual-haptic form recognition with task delay and sequenced bimodal input. Neuropsychologia, 1974, 12, 75-81.