

## Intermodal Equivalence of Stimuli in Apes

**Abstract.** *Orang-utans and chimpanzees can discriminate between two objects on the basis of tactile cues and select the one that matches a visually presented sample.*

In normal human adults the various sensory modalities appear to function as an integrated system. This integration is most clearly demonstrated when performance of a task using cues from one modality influences the performance of a task using cues from another modality. Thus, a problem which has been previously learned visually may be more readily solved when it is presented tactually, and a visual stimulus may be a cue for solution of a tactually presented problem. However, the extent to which this capacity for intermodal transfer is shared by other animals is not yet clear. Indeed, it has been suggested that symbolic language may be essential in the mediation of certain cross-modal phenomena (1). Attempts to demonstrate cross-modal phenomena in infrahuman animals have yielded negative, inconclusive, or weak results (2). The following experiment was designed to determine if apes possess the capacity to utilize visual cues to solve tactual problems.

In each trial of this experiment, the subject was presented three objects, or discriminanda, one of which (the sample) he could see but not touch and two others which he could touch but not see (the haptic objects). One of the two haptic objects was identical to the sample ("a match"), and the other was distinctly different. The subject's task was to observe the sample, feel the haptic objects, and select one. If the chosen haptic object matched the sample, subject was rewarded.

The test apparatus (Fig. 1) enabled subjects to reach through an aperture in order to feel the haptic objects while at the same time looking at the sample. All three discriminanda were suspended by thin chains from a pivoting bar. Stops prevented subject from pulling the haptic objects into view.

The discriminanda were a wide variety of highly distinguishable, three-dimensional objects, such as ceramic drill points, coiled springs, drawer handles, and paper clamps. These different objects were almost certainly unknown to the subjects before the experiment.

With the apparatus positioned out of subject's reach, a trial was prepared by placing three objects in their designated positions. Then the apparatus was moved close to the cage front and the

animal was allowed to observe the sample, feel the haptic objects, and indicate his choice by tugging one downward. If the response was correct, a small candy reward either dropped into the response aperture or was placed in the subject's hand. Then the entire apparatus was withdrawn, and the next trial was prepared. The placement (right or left) of the correct choice was varied at random, and evenly balanced over 100 trials. Each subject received 100 trials a day.

The experiment was divided into pretraining, phase I, and phase II. Although a total of 11 apes (two gorillas, two orang-utans, and seven chimpanzees, all between 2 and 4 years old) were selected as subjects, six were dropped during pretraining because of problems such as unresponsiveness, attempts to damage the apparatus, and temper tantrums. Thus, five apes (three chimpanzees and two orang-utans) participated in phase I. Three of these, one orang-utan and two chimpanzees, were available for phase II (3).

In pretraining, subjects learned to observe the sample presented in the window, to reach through the aperture and feel both objects, and to indicate a

choice by a distinct downward pull (about 2½ cm) on one object (4).

The stimulus objects of phase I were 20 separate visually presented discriminanda (A,B, . . . ,T), and 20 identical haptically presented objects (A',B', . . . ,T'). In phase I, subjects received several sets of 500 unit trials. During a set, each pair of objects (for example, AA') was associated with one other pair (for example, BB'), producing ten combinations (AA'/BB', CC'/DD', . . . , SS'/TT'). While both objects of a given combination (for example, A' and B') were haptically presented in each unit trial, the visually presented mates were alternated (A or B). The presentation of combinations was ordered so that, between two trials with a given combination, the other nine combinations always intervened. During the course of 20 trials, all objects were presented as the sample. This series was repeated for a total of 500 trials. For each of the subsequent sets, the discriminanda were regrouped arbitrarily into completely different combinations. For example, the presentation sequence was as follows: trial 1 A/A'B', 2 C/C'D', . . . , 10 S/S'T', 11 B/A'B', . . . , 20 T/S'T', . . . , 101 A/A'B', . . . , 500 T/S'T'; regrouping of pairs, trial 501 M/M'B', 502 G/G'K', . . . , 510 R/R'C', 511 B/M'B', . . . , 520 C/R'C', . . . ; regrouping, 1001 R/R'H', . . .

All five subjects completed the first two sets of 500 trials. In addition, four

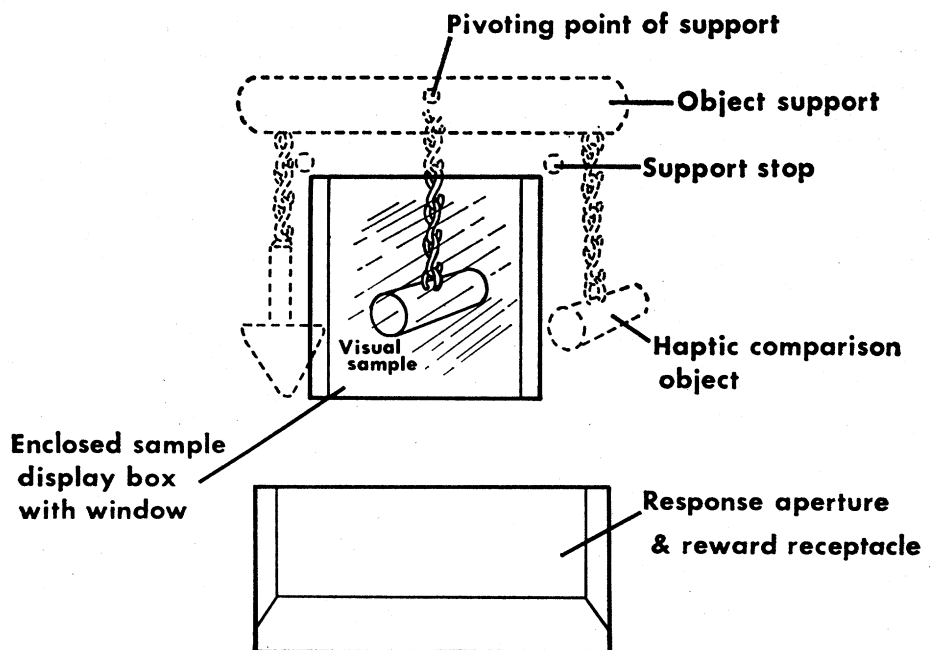


Fig. 1. Cross-modal matching to sample apparatus. The parts depicted by dashed lines are not visible to the subject. The visual sample is suspended from the center of the object support, enclosed in a box, behind a plexiglass window so that it may be seen but not touched by the subject. Conversely, the haptic objects, suspended at each end of the support, may be felt but not seen. The response aperture is about 40 cm wide.

of the subjects completed at least part of a third set, two completed a fourth set, and one subject completed a fifth set. Thus, in phase I the fewest trials completed by any subject was 1000, and the most was 2500. These discrepancies were caused by differences in starting dates due to individual differences in length of pretraining. The termination date was the same for all, and was due to factors unrelated to the experiment.

The results of phase I showed that initially subjects matched objects at about chance level but improved rapidly. By the end of the first set of 500 trials, four of the subjects were performing at better than 90 percent accuracy, with the remaining subject at better than 80 percent. When the discriminanda were recombined for the second set (beginning with trial 501), the accuracy of two subjects initially decreased slightly, while the other three performed at least as well as before. But from the middle of the second set, this high level (90 percent or better) was maintained by all subjects even when recombinations were introduced, for example, trials 1001 to 1020, and 1501 to 1520.

During the course of the experiment, subjects' response method also evolved: whereas at the beginning of phase I subjects usually felt both objects before choosing, with further training they responded immediately if the matching object was touched first.

Clearly, in phase I subjects were operationally matching to sample across sensory modalities. But the question remained, was their successful performance based on the perception of the similarity between the visible object and its mate (the concept of equivalence of stimuli), or were they performing a rapidly learned conditional response across modalities.

Phase II was designed to answer this critical question. Subjects were presented once with each of 40 unique combinations, composed of discriminanda not used previously, not repeated here, and with which subjects had had no experience. Ten of the unique trials were presented each day for a period of 4 days.

If the high level of accuracy in phase I was due to specific training with a limited number of objects, then performance on phase II would be chance. But if subjects had grasped the essential nature of the problem, "If A, then another A," their matching scores on

the 40 unique trials with novel discriminanda should be significantly better than chance.

The results of phase II clearly support the latter alternative, since the three subjects performed with a degree of accuracy significantly above chance (33, 31, 29 correct choices out of 40;  $\chi^2 = 18.55$ , d.f. = 2,  $P < .01$ ). Thus, we submit that this experiment demonstrates the presence in apes of a meta-modal concept of stimulus equivalence which is based on a mediation process independent of verbal language.

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#### References and Notes

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2. P. Blakeslee and R. Gunter, *Behaviour* **26**, 76-90 (1966); D. Burton and G. Ettliger, *Nature* **186**, 1071 (1960); G. Ettliger, *Behaviour* **16**, 56 (1960); L. Rothblat and W. Wilson, *J. Comp. Physiol. Psychol.* **66**, 549 (1968); J. Wegener, *ibid.* **59**, 450 (1965); W. Wilson, *Neuropsychologia* **3**, 363 (1965); W. Wilson and O. C. Shaffer, *Nature* **197**, 107 (1963).
3. Of the other two, one chimpanzee died in experimental surgery and one orang-utan was transferred to another facility.
4. Details of pretraining are available from us on request.
5. Supported by NIH grant FR-00165.

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#### Vitreous Water: Identification and Characterization

Yannas (1) has stated that he had found only one previous detailed article on the possible formation of vitreous water. In deference to the work which has been done on this subject in recent years, we feel it is necessary to correct the impression left by this statement.

There have in fact been quite a number of attempts (2-9) to prepare and characterize vitreous water, and the success to be accorded these depends to some extent on what one chooses to define as a vitreous substance. If we adopt the definition suggested recently by a National Research Council Materials Advisory Board Ad Hoc Committee (10) that a glass, or vitreous substance, is a solid giving a typical amorphous-phase x-ray pattern

and capable of exhibiting the glass transition (10), then the vapor-deposited amorphous ices studied by x-ray diffraction (2, 6, 7) or by electron diffraction (5) must be judged to have been inadequately characterized. If we accept that careful deposition from the vapor phase produces amorphous deposits that satisfy the first criterion, then by thermal studies, several of which have been performed (3, 4), one can in principle prove the existence of a vitreous form of water by detecting the change in heat capacity which occurs at the glass transition. However, until 1965, no such glass transition had been detected and hence no vitreous ice identified completely.

The first clear demonstration that an actual vitreous ice satisfying both criteria could be formed was presented by McMillan and Los (8), who carefully deposited water out of the vapor phase onto a copper surface held at liquid-nitrogen temperature. Differential thermal analysis in situ of the samples obtained revealed a characteristic glass transition at 139°K. Although the findings of McMillan and Los were later contested by Ghormley (9), who failed to find any transition in simple calorimetric studies of amorphous deposits, we are well satisfied, on the basis of our own experience in characterizing kinetically unstable aqueous glasses by differential thermal analysis, that McMillan and Los observed a true glass transition. There is no doubt that the glass transition temperature they reported is that expected from the extrapolation of plots of the glass transition temperature as a function of composition for binary molecular solutions such as H<sub>2</sub>O-H<sub>2</sub>O<sub>2</sub> (11), H<sub>2</sub>O-N<sub>2</sub>H<sub>4</sub> (12), and H<sub>2</sub>O-dimethylsulfoxide (13), electrolyte solutions such as LiCl-H<sub>2</sub>O (14) and Ca(NO<sub>3</sub>)<sub>2</sub>-H<sub>2</sub>O (15), and numerous other electrolyte solutions (16, 17). The findings of McMillan and Los are also substantiated by what is no doubt the most sophisticated piece of research yet performed on vitreous water, the adiabatic calorimetry studies performed by Sugisaki *et al.* (18) on in situ vapor-deposited material. These workers measured the actual increase in heat capacity ( $C_p$ ) of the glass as it passed from the vitreous to the supercooled liquid state and confirmed the glass transition temperature reported by McMillan and Los. They also noted that conditions of deposition were critical in determining whether the deposit