Assessment and Training of Visual and Tactual Stimulus Equivalence

Brooke Ann Rigney
Western Michigan University

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Visual-tactual equivalence was examined within the stimulus equivalence paradigm originally developed by Sidman in studies of verbal behavior (1971). Experiment I assessed for equivalence between tactually and visually presented objects. In Experiment II, colors and textures were added to the objects and the effect of modality distinctive stimuli on equivalence was examined. Experiment III then studied the establishment of equivalence with these modality distinctive stimuli using the Sidman stimulus equivalence paradigm.

Visual-tactual equivalence was demonstrated in Experiment I. Experiment II demonstrated that equivalence could be disrupted by modality distinctive stimuli. Experiment III then showed that equivalence could be demonstrated between distinctive visual and tactual stimuli when training was accomplished in accordance with the stimulus equivalence paradigm. This study accomplished an expansion of the equivalence paradigm to an area other than verbal behavior and provided evidence of a method by which tactual visual equivalence may be established.
ACKNOWLEDGEMENTS

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Brooke Ann Rigney
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Rigney, Brooke Ann, M.A.

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INTRODUCTION

The recognition of stimuli across sense modalities is so common an occurrence that it is rarely pondered by most people, but it has intrigued philosophers and scientists for many years. Marks (1978) described an Aristotelian doctrine of "sensus commonus" which states that a common function of the sense modalities, especially vision and touch, is the perception of size, shape, motion, rest, and number. Aristotle referred to these stimulus characteristics as "common sensibles." Cross modal perception became a prominent subject of philosophical discourse in the 17th century with a famous correspondence between Molyneux and Locke. In this correspondence, Molyneux posed a yet unanswered question; would a blind man restored to sight recognize visually the objects he had previously known only tactually? (cited in Bushnell, 1981). In the 17th century, the investigation of this question and of other issues related to the equivalence of the senses involved discussion, discrimination, and categorization of sensory qualities. It was based in many ways on Aristotle's original doctrine. Galileo, Hobbes, Locke, and other philosophers of the time debated issues that dealt with the distinction between what is perceived and what
physical properties produce the human perceptions that are often common across modalities (Marks, 1978).

The 19th and 20th centuries progressed from philosophical debates to more scientific studies and theories of the interrelationship of touch and vision. Historically, there have been two predominant and opposing theories regarding intermodal perception.

The first is based on the doctrine of specific nerve energies and claims that tactual and visual sensory systems are originally separate neurological systems that become integrated as an organism develops (Abravenel, 1981; Gibson, 1969; Jones, 1981). Associations between vision and touch, accomplished by simultaneous or temporally contiguous stimulations of the two senses, are thought responsible for integrating the sensory systems and increasing the neurological interconnections between initially independent modalities. Although there is little to support this position (Jones, 1981), research indicating that cross-modal matching improves as a child gets older is often cited as evidence for it (Bushnell, 1981). It is also known, however, that intramodal responding increases in accuracy as a child gets older (Jones, 1981). It is therefore possible that the changes occurring during development that effect intermodal behavior are a result of increases in intramodal efficiency and accuracy in discrimination due to practice and
learning rather than cerebral or neuronal integration of the modalities.

A second theory describes a "unity of the senses" (Bower, 1977). This "unity" is thought to be present at birth such that stimulations of the senses in infancy effect some global neurological system instead of effecting separate perceptual subsystems. Differentiation of the senses occurs with the development of the organism. In later life then, the sense modalities can in some way perceive parallel kinds of similarities or differences between stimuli such that a type of redundancy occurs. Thus, the organism is provided with the same information by both senses due in some way to the physiological unity or basis for the senses. The proponents of the "unity of the senses" hypothesis do not attempt to explain cross modal perception through environmental variables or learning. They acknowledge the role of learning only in the role it is proposed to play in the differentiation of the senses during early development. The theorists consider only hypothetical perceptual organization and, as a result of the hypothetical nature of their theory, there is no direct empirical evidence for their position. Its support is derived mainly from the compatibility of the theory with popular positions or ideas of researchers in the field and the lack of strong contraindicating evidence.
In addition to these two historically prominent theories, new explanations of cross modal perception have occurred in the theories and discussions of more contemporary researchers.

Some researchers have followed the unity of the senses philosophy and proposed that cross modal equivalence can be understood using a concept of schema (Abravenel, 1981). Tactual or visual contact with a stimulus is traditionally thought to result in the acquisition of information that is stored in the nervous system. This stored information is thought to be a schematized version of the original stimulus. The schematized form to which the original stimulus is transformed is assumed not to be specific to the modality from which the information was extracted. Therefore, cross modal equivalence is thought possible because the information handling system, that is, the information extraction and schematization, is the same for both tactual and visual perception of a stimulus. While the manner in which stimuli are stored in the nervous system and their neuronal interconnections may prove to provide a great deal of information about how the two systems are integrated, we are not at a stage in physiological knowledge to investigate cerebral operations. Therefore, the ideas of schema, like the unity of the sense and the doctrine of specific nerve energies theories, are only
metaphorical inferences and cannot be substantiated with objective, empirical data. Models of neurological processes produce a "conceptual nervous system" (Skinner, 1976) that is comprised of metaphors for which we can provide no practical evidence. As Skinner (1976) points out, these models may appear to serve a purpose in the infancy of physiological knowledge, but actually serve to direct researchers' attention away from available, observable information.

In her 1969 article, Gibson proposed a theory of cross modal equivalence that considered available environmental information. She studied the characteristics of environmental stimuli and proposed that the similarities between touch and vision were due to topographical features that appeared similar in each modality, such as size and shape. She called these features "amodal" since they are not specific to any sense modality. Amodal stimuli include curves, points, corners, and other characteristics such as movement. While a newer theory, it is quite reminiscent of Aristotle's original doctrine of sensus commonus. Although Aristotle's common sensibles or Gibson's amodal features may account for much of man's perception across modalities, it seems that such a theory is unable to account for all cases of cross modal equivalence since not every stimulus has features that look the way they feel.
Another possible explanation of cross modal equivalence is that associations between visual and tactual stimuli are learned through operant conditioning beginning in infancy. Bushnell (1981) proposed that chance contact with objects in the visual field can result in movement, sound, or tactual sensations that are pleasurable and likely to reinforce the intermodal behavior of touching an object in response to the visual stimulus of that object. Through such experience a direct association between the tactual and the visual stimuli can occur. Intermodal behavior such as identical tacting or discrimination responses across modalities can be accomplished as a result of such experience.

One other explanation of cross modal responding that is found in the literature is symbolic-linguistic coding. Brown and Lennenberg (1954) found that items presented visually were more easily identified if verbal descriptors were used. Inspired by this finding, Koen (1971) studied whether or not verbal descriptors aided cross modal identification of objects. Based on the results of a post test inquiry regarding the use of labels during the experiment, Koen defined high and low label use in a cross modal discrimination task for each subject. Due to the lack of clear correlation, he concluded that verbal mediators did not enhance cross modal responding. Gaydos (1956) also studied verbal labeling via post test
interview. His study also indicated that subjects sometimes do describe or label the stimuli, but could not definitively say whether or not labeling had a role or how that role might function. Like the schema approach, symbolic-linguistic coding is quite cognitively and hypothetically based, but it need not be. It is thought that a label or description of the object might be a necessary link between the two systems. This label or description is normally assumed to be an internal, mental linking process. The label is, however, a verbal behavior. In describing verbal behaviors, Skinner (1957) uses the term "tact" when referring to a response form that is controlled by a nonverbal stimulus. Such a stimulus could be an object presented in any mode, an aspect or property of that object, or some type of relationship. A tact includes what is traditionally referred to as a label, but no internal processes are inferred. Whether overt or covert, verbal behavior does not need inferred internal processes to explain or describe it since it, like any other behavior, operates under the control of environmental antecedents and consequences. Tacting may occur concurrently with equivalence and may bear some functional relation to it. Such possible relationships have, however, not been adequately studied. Garvill and Molander (1971) claimed that their research provided evidence for verbal
mediation. Using an anticipation method paired associate procedure, they taught subjects to verbalize a nonsense syllable in response to the visual or tactual presentation of an object. The nonsense syllable was then paired with a number by the same procedure until a criterion of two errorless trials was met. Then the object was presented in the opposite modality and, using the anticipation paired associate procedure, the subject was taught to pair this with the numbers. Since the modality presented second was learned more easily, Garvill and Molander claimed that the paired verbal stimulus mediated a transfer of learning. Of course, if visual and tactual stimuli are, in some way, equivalent, such results might be expected. Also, it is not clear from the study whether or not the results would have been different if nonverbal stimuli had been used instead of verbal stimuli.

It is apparent that, although cross modal perception is a common occurrence, it is not yet well understood. It is unlikely that one single type of experience accounts for all cross modal behavior. It seems quite possible that stimuli can have topographical features that are common to both touch and vision. It is also likely that some associations can be learned through contiguity of presentation and inherent reinforcing characteristics of the stimuli. However, these
explanations do not account for the equivalence of touch and vision when no common features or previous direct associations are present. An area outside of the traditional cross modal perception literature may contribute to the understanding of the development of cross modal equivalence in such cases. This area is experimental behavior analysis, specifically, research in stimulus equivalence.

Sidman (1971; 1972), Sidman and Cresson (1973), and Sidman, Cresson, and Wilson-Morris (1974) originated the behavioral study of stimulus equivalence. Sidman (1971; 1972) accomplished this while developing a method for teaching reading comprehension to a retarded boy. The method involved teaching the child to respond to an auditory stimulus, such as the word "cat," by selecting the corresponding picture of a cat. He also taught the child to respond to the auditory stimulus with the appropriate selection of the printed word "C A T." He found that after training these two associations, the boy could select the printed word in response to the picture and select the picture in response to the printed word without further training. A schematic drawing of these relationships is presented in Figure 1. Sidman explained these results in terms of stimulus equivalence; the three stimuli had become functionally equivalent to one another. These equivalent stimuli were then described as
Sidman & Tailby (1982) operationally defined stimulus equivalence to distinguish it from identity matching or conditional discriminations. They described a three part test for an equivalence relation. These tests were
based on the mathematical definition of an equivalence relation. The first test was one of reflexivity: if $A$, then $A$ ($A \equiv A$). Sidman & Tailby related this to simple identity matching. The second test was for symmetry: if $A$, then $B$ and if $B$, then $A$ ($A \equiv B$). This symmetry test was comparable to conditional discrimination tests. The third property tested was transitivity. It involved the introduction of a third stimulus. If $A$ has a conditional relation with $B$, and $B$ has a conditional relation with $C$, then $A$ must have a conditional relation with the third stimulus $C$ ($A \equiv B$ and $B \equiv C$, then $A \equiv C$).

Sidman, Rauzin, Lazar, Cunningham, Tailby, Carrigan (1982) noted that researchers often assumed that stimuli were equivalent if they could be conditionally associated with each other. That is, if a subject consistently responds to stimulus $A$ with stimulus $B$, researchers often assume that these stimuli are then similar, identical, or equivalent. Also, the term matching-to-sample is often used to describe these conditional discriminations.

The traditional cross-modal literature makes such assumptions. Studies refer to cross-modal equivalence or cross-modal transfer when they have only demonstrated a conditional discrimination by testing for reflexivity and/or symmetry. Jones (1981) states that in "any cross-modal matching experiment the subject is asked to compare one or more standard items with one or more comparison
items" (p. 109). In a typical experiment a subject is presented with a stimulus in one modality and asked either to select it from several items in the other modality or to state whether a stimulus presented in another modality is the same or different than that first presented. Presentation of stimuli is either simultaneous (simultaneous matching) or successive (zero delay matching). In a review, Jones lists fifteen experiments which test visual-visual (v-v), tactual-tactual (t-t), visual-tactual (v-t), and tactual-visual (t-v) matching. In terms of Sidman et al.'s (1982) operational definition, the v-v and t-t experiments would satisfy a test of reflexivity ($A \rightarrow A$ and $B \rightarrow B$) and the v-t and t-v tests would satisfy the requirement for symmetry ($A \rightarrow B$; $B \rightarrow A$). A test of transitivity (if $A \rightarrow B$ and $B \rightarrow C$, then $A \rightarrow C$) is, however, lacking.

The first experiment of this study tested for equivalence via this transitivity. Normally transitivity would be established by training the subject to select $B$ when presented with $A$ ($A \rightarrow B$) and $C$ when presented with $B$ ($B \rightarrow C$) and then to test for the relationship $A \rightarrow C$. In this case $A$ is the visual presentation of a nonsense object, $B$ is a symbol and $C$ is the tactual presentation of that same object. Nonsense objects were chosen to ensure that the subjects had had no prior learning history with respect to the experimental stimuli since
such history could obviously confound the test results. If \( A \rightarrow C \) already exists as part of the subject's repertoire, then \( B \rightarrow C \) should be evidenced if tested for after training only \( A \rightarrow B \). An inherent ability to respond cross modally is often assumed in the traditional literature (Gibson, 1969; Jones, 1981) and this experiment would present a more stringent test of cross modal responding and the equivalence of visual and tactual stimuli.

It is possible that such an equivalence could be dependent on topographical features of the stimuli common to both senses as postulated by Gibson (1969). Yet it is also apparent that similar topographical features do not account for equivalence in every instance. In an experiment by Bjorkman, Garvill, and Molander (1965) it was shown that visual-tactual discriminations decrease if there are distinctive visual or tactual aspects of the stimuli present. Bjorkman et al. used three dimensional nonsense objects with color as the distinctive visual stimulus and weight as the tactualy distinctive feature. The experiment demonstrated that people usually attend to the most salient features of a stimulus unless specifically told to attend to common features. If an object's salient features are not common to both touch and vision and if equivalence still occurs, then equivalence must have been learned by some other method. One such method
may involve experience similar to that described by Sidman's stimulus equivalence paradigm. The possibility exists that visual and tactual stimuli can become equivalent stimuli by becoming members of the same stimulus class through the establishment of a conditional relationship with a third stimulus in a stimulus equivalence paradigm. Experiment II tested for reflexivity (A r A; B r B) and symmetry (A r B; B r A) with nonsense objects that have both distinctive visual and tactual features and amodal characteristics. Experiment III then tested whether equivalence, or transitivity, can be established for such stimuli through the stimulus equivalence paradigm introduced by Sidman.
EXPERIMENT I

Method

Subjects

The voluntary participation of three males and three females, ages 19-29, was enlisted. In order to ensure that no individual perceptual deficits interfered with testing or confounded the test results, all subjects were screened to be sure that they had normal vision or vision that was corrected to normal and that they had no tactual perception problems. Screening was based on the subject's verbal report and did not include proof of a physical examination.

Setting and Materials

The subject was seated at a table on which two boxes were placed side by side. One of the boxes was five sided, with a closed end facing the subject and the open end facing the experimenter. This box was used to store materials when they were not in use during the experiment. The other box was four sided and was placed such that an open end faced both the subject and the experimenter. It was used to present the tactual stimuli. A black cloth was draped over the boxes to ensure that
stimuli were not seen during tactual presentation.

Two different types of stimuli were designed for use in this experiment. One type was nonsense objects similar to those used by Caviness in an unpublished work (cited in Gibson, 1969). Six different objects were created using modeling clay. They were all the same size and weight and all were convex on one side with five protruberances and a central hump on the other. The nonsense objects were also consistent in texture and color, having been sprayed with cream colored enamel paint. The objects are represented in Figure 2.

![Figure 2. The Nonsense Objects Used in This Experiment.](image-url)
The second set of stimuli that was created for the experiment consisted of six two dimensional symbols that bore no resemblance to the nonsense objects described above. These symbols are shown in Figure 3. Each symbol was drawn in black on a white 8 1/2" x 8 1/2" card. Additionally, six 18" x 18" cards were made on which the six symbols were drawn to allow for easy presentation of all six symbols at one time since this was often required during the experiment. On these arrangement cards, the symbols were positioned in a circular fashion, with order of arrangement different for each card. A random number table was used to select the symbol positions.

Figure 3. The Six Symbols Used in This Experiment.
When used, the symbol arrangement card or the individual symbol card was held by the experimenter in a vertical position about 18" in front of the subject. Nonsense objects were placed on 8 1/2" x 8 1/2" black cards which were put directly in front of the subject when used. When both symbols and visual presentation of the objects were required, the objects were placed closest to the subject and the symbols were then held between the objects and the boxes.

**Procedure**

**Phase I: Training Visual Object-Symbol Responding**

Phases I and II were intended to establish the visual object-symbol (v-s) symmetry that is required prior to a test of visual object-tactual object (v-t) transitivity in accordance with the Sidman (1971) stimulus equivalence paradigm. In this first phase the subjects were trained to select the appropriate symbol (s) when presented with the nonsense object visually (v). In Phase II they were taught to select the appropriate nonsense object when presented with a symbol. The paradigm for Experiment I is diagramed in Figure 4.

Subjects were shown a nonsense object and then, after unlimited time for inspection, the object was removed and they were presented with the corresponding symbol. In
each case they were told to look at the stimulus, but not to touch it, and that they would be asked to select the symbol from a group of symbols when shown the object
and vice versa. Since one presentation of each object and its corresponding symbol does not constitute training a symmetry relationship nor does it give experience in making the type of discrimination responses that were to be required in this experiment, the experimenter again put down the same object but this time asked the subject to select the appropriate symbol from a six symbol arrangement card. Social reinforcement was given for correct selection and feedback was provided for an incorrect response. The remaining five object/symbol pairs were presented in this manner. After this introduction of the stimuli, training to criterion occurred in which presentation of the objects and symbol arrangement cards was repeated until 100% correct responding was accomplished twice successively for the entire set of object/symbol pairs. The presentation of the set of six pairs was considered a trial. The order of object and arrangement card presentation was determined by a random number table.

Phase II: Training Symbol-Visual Object Responding

Since the objects were introduced in Phase I, in this phase only criterion training was accomplished. The subject was presented with a symbol. After unlimited time for inspection, the symbol was removed and the set
of six objects was presented. The subjects were asked to select the appropriate object. This was repeated until 100% correct responding was accomplished twice successively for the entire set of object/symbol pairs.

**Phase III: Testing Tactual Object-Symbol Responding**

According to the typical stimulus equivalence training paradigm, the symmetry relationship between the visual object and the corresponding symbol would be taught as it was in phases I and II. Then the symmetry relationship between the tactual object (t) and the corresponding symbol would be taught and, following this training, the equivalence, or transitivity, between the visual and tactual stimuli would be tested. Since it is traditionally assumed that an equivalence between visual and tactual stimulation from the same object exists in some way as part of every human's repertoire of responding to the environment (Gibson, 1969; Jones, 1981), the t-s relationship will not be taught in this experiment. According to the transitivity equation, if v = s (the relationship which has been trained) and v = t (a relationship which is assumed to exist), then t should equal s as well. This phase tested whether or not t = s. Phase IV tested whether or not s = t. If t = s and s = t, then visual-tactual equivalence can be assumed to have
existed since the \( v-t/t-v \) relationship was a necessary prerequisite to the \( t-s/s-t \) relationship. Also, if \( t \neq s \) and \( s \neq t \), the assumption of inherent equivalence of visual and tactual stimuli is brought into question.

In order to control for and to investigate the potential effect of the order of \( t-s \) and \( s-t \) testing, the subjects were divided into two groups. Group 1 was exposed to phase III prior to Phase IV and therefore to \( s-t \) testing before \( t-s \) testing. Group 2 was exposed to Phase IV prior to Phase III and therefore experienced \( t-s \) testing before \( s-t \) testing.

In this phase, the subject was asked to place his/her hand under the black cloth and into the box. S/he was told that s/he would be handed an object and then, after the object was removed, be asked to select the appropriate symbol from a set of symbols. The order of presentation of both the objects and the symbol arrangement cards was determined by a random number table. No praise or feedback was given for correct or incorrect responding.

**Phase IV: Testing Symbol-Tactual Object Responding**

The subject was presented with each individual symbol card and asked to select the appropriate object from a set of six objects presented to him/her in the
box. The arrangement of the set of objects was determined by a random number table and differed for each presentation of each symbol card. Again, no feedback or praise was given.

**Phase V: Testing Visual Object-Tactual Object Responding**

In this phase and Phase VI, a direct test of the symmetry between tactual and visual responding was accomplished. If transitivity was shown in phases III and IV, it would be expected that t-v/v-t symmetry would also be demonstrable by direct testing. If the transitivity was not shown, it would be expected that the t-v/v-t symmetry would also not be seen.

The subjects remained divided into the same groups as in Phases III and IV. Group 1 was exposed to v-t testing before t-v testing; Phase V was presented before Phase VI for this group. Group 2 was presented with Phase VI before Phase V and therefore was exposed to t-v testing prior to v-t testing. The purpose of this was the same as it was for previous phases; it was intended to control for and investigate the effects of order of testing.

One of the objects was presented visually to the subject. The subject was instructed to look at it and was told s/he would be asked to select it tactually from
several others. The object was then removed and placed in the box with five others. The subject was asked to select the correct object. Each object was presented in this manner and object arrangement and order of presentation were again determined by random number tables. No feedback or praise was given.

**Phase VI: Testing Tactual Object-Visual Object Responding**

The procedure was the same as that for Phase V, except that the object was first presented tactually and the selection was then made from objects presented visually.

**Reliability Data**

Reliability data were collected for three of the six sessions. The reliability observer was trained by: (a) doing the experiment himself (b) performing the experiment for practice with the primary researcher and (c) two hours of instruction and practice in reliability data collection. Data collection was accomplished by having the research assistant record the subject's responses. In the phases involving symbol or visual object presentation, he was positioned just behind the subject. For tactual object presentation he was positioned just behind the experimenter and was required to record his data before the experimenter recorded hers. The positioning
of the subject and the order of recording ensured that the reliability data was not influenced by the experimenter's recordings. Reliability was calculated by dividing the number of agreements by the number of agreements plus disagreements of correct and incorrect responding for the entire session and multiplying by 100.

Results

Phase I: Training Visual Object-Symbol Responding

All six subjects learned to select the appropriate symbol when presented with a nonsense object. The mean number of trials to criterion was 8.2 with the number of trials for each subject being 7, 8, 7, 8, 9, and 10 for Lorri, Robin, Ron, Paul, Angie, and Josh, respectively.

Phase II: Training Symbol-Visual Object Responding

Five of the six subjects met criterion in the minimum of two trials. One subject, Josh, required three trials to meet criterion. The mean number of trials for all six subjects was therefore, 2.2. A paired T-test indicated that this mean was significantly different than that for phase I (T=16.43; p<.05). Choosing an object in response to symbol presentation was mastered more easily after the subject had first learned to choose the symbol in response to the object. Thus, the second part of the
symmetry paradigm was accomplished more readily than the first part (i.e. \( B = A \) was learned more quickly than \( A = B \) when \( A = B \) was taught first).

**Phase III: Testing Tactual Object-Symbol Responding**

Lorri, Paul, and Josh, who received this phase prior to phase IV, correctly selected a symbol when presented with an object tactually 5 (84%), 3 (50%), and 4 (67%) times out of six, respectively. Their mean number correct was 4 (67%). According to an independent T-test, this mean was not significantly different from that of group 2 who had experienced phase IV prior to this phase. The group 2 mean was 4.4 (74%) and individual numbers correct were 4 (67%), 4 (67%), and 5 (84%) for Robin, Ron, and Angie, respectively. The overall mean was 4.2 (70%).

The results for phases III, IV, V and VI are presented in Figure 5.

**Phase IV: Testing Symbol-Tactual Object Responding**

The mean number of correct responses for group 1, group 2, and overall was 3.7 (62%). A paired T-test indicated that this overall mean was not significantly different from that of Phase III. Numbers correct for each subject were 4 (67%), 2 (33%), 5 (84%), 4 (67%), 4 (67%), and 3 (50%) for Lorri, Paul, Josh, Robin, Ron, and
Angie, respectively.

Figure 5. The Results of Phases III, IV, V, and VI of Experiment I. (Bar graphs represent overall mean percent correct. Individual data are also presented for each phase with group membership of the subject indicated.)
Phase V: Testing Visual Object-Tactual Object Responding

Mean number correct for group 1 was 4.4 (74%) and for group 2, 5 (84%). These means were not significantly different according to an independent T-test. The overall mean was 4.7 (79%) and a paired T-test showed that it did not differ significantly from the means of phases III or IV. Individual subject data were 6 (100%), 3 (50%), 4 (67%), 6 (100%), 4 (67%), and 5 (84%) for Lorri, Paul, Josh, Robin, Ron, and Angie, respectively.

Phase VI: Testing Tactual Object-Visual Object Responding

The mean for group 1 was 4.7 (79%) and for group 2 it was 5.4 (90%). These means were not significantly different according to an independent T-test. The overall mean was 5.0 (84%). A paired T-test indicated that it was not significantly different from the means of phases III, IV, or V. The number correct for each subject was 6 (100%), 5 (84%), 4 (67%), 6 (100%), 4 (67%), and 6 (100%) for Lorri, Paul, Josh, Robin, Ron, and Angie, respectively.

Reliability Data

Reliability data were collected for Paul, Robin, and Ron. Reliability figures were 100%, 98.8%, and 98.8%, respectively. Mean reliability for Experiment I was
Discussion

Phases I and II showed that subjects were able to learn to discriminate the nonsense objects and to learn to select a matching symbol for each object. Phases I and II therefore accomplished the first leg of the Sidman stimulus equivalence paradigm.

Phases III and IV provided evidence that, without training, subjects could match the object and symbol when the object was presented tactually instead of visually. If equivalence did not, in some way, already exist, then it would have been expected that the visual object/tactual object leg would have had to have been trained before this could occur. Errorless matching in these phases was not seen, indicating that the visual-tactual modes were not perfectly equivalent without training.

As would be expected, Phases V and VI provided support for the findings in Phases III and IV; reflexivity in responding to visual and tactual object presentation was seen, though again not without errors.
EXPERIMENT II

Method

Subjects

Six subjects of the same type as those used in Experiment I participated in Experiment II. The subjects ages ranged from 20 to 23.

Setting and Materials

The setting was the same as that described in Experiment I. The materials were also the same except that the individual symbol cards and the symbol arrangement cards were not used and the nonsense objects each had one of the following attached to the convex side with removable tape: cotton, sandpaper, Velcro, double stick tape, thin velvet, glue dried into a non-pointed hump. On the center hump of each object was placed a strip of one of the following colors: black, red, blue, green, yellow, orange. The purpose of these additions will be explained in the procedures section.

Procedure

This experiment was designed to test the effects of distinctive visual and tactual aspects of stimuli on the
establishment of a symmetrical relationship, since studies (Bjorkman, Garvill, & Molander, 1965) have shown that such distinctive aspects disrupt relationships between tactual and visual stimuli and therefore would also be expected to effect transitivity. "Distinctive" as it is used here means some very salient feature that is available to only one sense modality. In this experiment, distinctive visual stimuli are colors and the distinctive tactual stimuli are textures that are not made available for visual inspection.

Phases I and II were tests of simple reflexivity and were intended to provide some exposure to the stimuli and to provide practice in discriminating each form within a single modality. In phases III and IV the visual-tactual symmetry of the objects with the distinctive stimulus aspects was tested; Phase III tested t-v and Phase IV tested v-t. Diagrams of the procedures for Experiment II are presented in Figure 6.

The six subjects were divided into two groups of three. One group experienced visual training or testing before tactual training or testing. That is, they were presented with Phase I before II and Phase III before IV. Group two was presented with Phase II before Phase I and Phase IV before III. Group two therefore received tactual training or testing before visual training or testing. This subgrouping was accomplished in order to
investigate and control for possible effects due to the order of exposure to the two modalities.

Figure 6. A Diagram of the Experimental Manipulations of Experiment II.

**Phase I: Visual Object Training**

The subject was presented with a nonsense object with a strip of color on it. S/he was told to look at it because s/he would be asked to identify it in a group of
similar objects. The subject was not allowed to look at
the convex side of the objects where the textures were
placed during tactual responding. (This rule was estab­
lished to ensure that in phases III and IV the subject
did not simply assume that the objects that were pre­
sented visually were not the same as those presented
tactually because the ones presented tactually had some­
thing on the back while the ones presented visually did
not.) The object was then removed and presented with
five other objects from which the subject was asked to
identify the object s/he had just seen. Each object was
presented in this manner; the presentation of all six
objects constituted a trial. Praise was given for
correct responses and feedback was given for incorrect
responses. This was repeated until 100% correct respond­
ing was accomplished twice successively.

Phase II: Tactual Object Training

The same basic procedure used in Phase I was used in
this phase, except that the tactual stimuli were attached
to the objects and the objects were only presented
tactually.

Phase III: Testing Visual Object–Tactual Object
Responding

The subject was presented with an object visually
and then asked to select it from six objects tactually (attachable tactual stimuli in place). Again, this procedure was repeated for all objects and no praise or feedback was given.

Phase IV: Testing Tactual Object-Visual Object Responding

The subject was presented with an object tactually (attachable tactual stimuli in place). S/he was then shown it and five other objects (all with attachable tactual stimuli now removed) and asked to identify the object s/he just felt. The procedure was repeated for the entire set of objects and no praise or feedback was given for correct or incorrect responding.

Reliability Data

Reliability data were collected by the same person who assisted with Experiment 1. He was trained in the same manner, accept that the two hours of instruction were not repeated. Calculations were also accomplished in the same manner.

Results

Phases I & II: Visual Object Training & Tactual Object Training

After presentation of a nonsense object, all six
subjects were able to select that object from a group of objects presented in the same modality. One hundred percent correct responding occurred for both visual and tactual object presentation such that the two trial criterion was met with the first two trials. No difference in performance was therefore observed for subjects first presented with phase I (group one: Annie, Mary, John) and those first presented with phase II (group two: Russ, Jason, Roger).

Phase III: Testing Visual Object-Tactual Object Responding

All six subjects selected incorrect objects throughout this phase; each time a subject was presented with an object visually s/he selected an incorrect tactual match. Mean correct for each group and overall was, therefore, 0.

Phase IV: Testing Tactual Object-Visual Object Responding

When asked to select an object visually following its tactual presentation, three of the six subjects, John, Mary, and Russ, chose an incorrect object each time. Two other subjects, Jason and Roger, selected the incorrect object five of six times and one subject, Annie, responded incorrectly four of six times.

Therefore, the number of correct selections from
group one, who experienced Phase III before IV and therefore received visual tasks prior to tactual tasks, was 0, 0, and 2. From group two, who received tactual tasks before visual tasks (Phase IV before III), the number correct was 0, 1, and 1. Mean correct was less than one (.66) for each group and overall.

The results of Experiment II are presented in figure 7.

Figure 7. Experiment II Results. (The number of correct responses for each subject in the two groups is depicted by the bar graphs.)
Reliability Data

Reliability data were collected for John, Mary, and Russ. Reliability was 100% for each subject.

Discussion

Experiment II demonstrated that subjects were able to select an object with a modality distinctive aspect if it was presented in the same mode, but were unable to do so if it was subsequently presented in a different mode.

Recall that subjects in Experiment I showed that equivalence was generally evidenced with these nonsense objects when no modality distinctive features were present. In this experiment, when distinctive features were present, subjects did not show equivalence. These results indicate that responding can be controlled by the more salient features of objects. It is therefore likely that in Experiment I, subjects were responding to common topographical features but that when salient stimuli were added in Experiment II, subjects attended only to these and therefore could not show equivalence because they had not attended to the features necessary to do so. In this way the results of experiment II provide support for Gibson's contention that when subjects are able to demonstrate equivalence, they are responding to topographical features of the stimuli that are common to both senses.
It is apparent that when salient stimuli are present, equivalence between tactual and visual modes can be disrupted. It is possible that people are able to respond in other ways to environmental stimuli to overcome disruption from distinctive features so that they still demonstrate equivalence. Experiment III investigated such a possibility.
EXPERIMENT III

Method

Subjects

Six subjects like those that participated in Experiment II participated in Experiment III. Their ages ranged from 20 to 39.

Setting and Materials

The setting and materials were the same as those used in Experiment II, except that the individual symbol cards and symbol arrangement cards described in Experiment I were also used.

Procedure

This experiment assessed whether or not transitivity could be established for objects with distinctive visual and tactual stimuli. That is, since Experiment II showed that such objects were not equivalent in the manner traditionally tested (i.e., testing for symmetry), is it possible that equivalence between tactual and visual stimuli can be established using Sidman's stimulus equivalence training paradigm? Figure 8 diagrams the use of
this paradigm in Experiment III.

Figure 8. The Stimulus Equivalence paradigm of Experiment III.

Phase I: Training Visual Object-Symbol Responding

In this phase and Phase II, visual object-symbol...
symmetry was established; Phase I taught v-s responding and Phase II taught s-v responding. Such symmetry is a necessary first step in the establishment of transitivity according to the Sidman training paradigm.

In this first phase the subject was taught to select a symbol from a symbol arrangement following the visual presentation of a corresponding nonsense object. This was accomplished using the procedures described in Phase I of Experiment I.

**Phase II: Training Symbol-Visual Object Responding**

The subject was taught to select a nonsense object from six objects presented visually after being presented with the corresponding symbol. This was accomplished using the procedures described in Phase II of Experiment I.

**Phase III: Training Tactual Object-Symbol Responding**

The second necessary symmetry relationship in the establishment of transitivity was accomplished in this phase and Phase IV; t-s responding was taught in Phase III and s-t was taught in Phase IV.

In this phase the procedures described in Phase I of Experiment I were used except that the nonsense objects were presented tactualy instead of visually.
Phase IV: Training Symbol-Tactual Object Responding

In this phase the subjects were taught to select a nonsense object when presented with a symbol. This was accomplished using the procedures described in Phase II of Experiment I, again with the exception that the nonsense objects were presented tactually instead of visually.

Phase V: Testing Visual Object-Tactual Object Responding

The final two phases of this experiment tested transitivity. Since v=s/s=v and t=s/s=t relationships were taught in phases I and II, it follows that if the transitivity equation holds, then v should equal t. Therefore, Phase V tests the v-t relationship and Phase VI tests t-v responding.

In this phase, the subject was presented with a nonsense object visually (distinct tactual stimuli removed). After unlimited time for visual inspection of the object by the subject (again with no inspection of the convex side allowed), the object was removed and the distinctive stimuli added. It and five others were placed inside the box. The subject was then asked to select the nonsense object s/he had just seen. No feedback was given for correct or incorrect responding.
Phase VI: Testing Tactual Object-Visual Object Responding

After all six objects were tested in Phase V, the objects were presented tactualy in a different order (with distinct stimuli in place) and the subject was asked to select the object he had just felt from six objects presented visually (distinct stimuli removed). Again, no feedback was provided.

Reliability Data

Using the same assistant, reliability data collections and calculations were accomplished in the same manner that they were in the first and second experiments.

Results

Phase I: Training Visual Object-Symbol Responding

All six subjects learned to select a symbol when presented with an object with a distinctive color strip on it. Group one subjects, Julie, Margie, and Andy, experienced phases I and II before phases III and IV. They met criterion after eight, six, and six trials respectively. The subjects of group two, Bob, Jerry, and Chris, who had first been exposed to phases III and IV, met criterion after two, five, and four trials respectively. The mean number of trials for group one was 6.7,
and for group two it was 3.7. An independent T-test indicated that these means were not significantly different. The overall mean for all six subjects was 5.2. The results of phases I, II, III, and IV are presented in figure 9.

Figure 9. Number of Trials to Criterion for Phases I-IV. (Bar graphs represent means from groups 1 and 2 and data points represent individual subject data.)
Phase II: Training Symbol-Visual Object Responding

Five of the six subjects met criterion in the minimum two trials. One subject, Margie, required five trials to learn to select an object when presented with its corresponding symbol. The mean number of trials to criterion was 3 for group one, 2 for group two, and 2.2 overall. The difference in the means of the two groups was not significant according to an independent T-test.

Phase III: Training Tactual Object-Symbol Responding

In this phase the subjects of group 1, Julie, Margie, and Andy, learned to select an object tactualy when presented with a symbol in 9, 6, and 6 trials respectively. The number of trials for group two were 4, 9, and 8 for Bob, Jerry, and Chris, respectively. The mean number of trials was 7 for both groups and overall. A paired T-test was conducted to compare Phase I and Phase III performance. It indicated group 2's performance in Phase III was significantly different than its performance in Phase I (T=5.0; p<.05). No such significant difference was found for group 1.

Phase IV: Training Symbol-Tactual Object Responding

Again, for all subjects except Margie, the criterion was met in the minimum two trials. Margie required six
trials to master the s-t relationship. The mean number of trials for group one was 2, for group two it was 3.4, and overall it was 2.7. An independent T-test indicated that the difference in the two groups' results was not significant.

Figure 10. Percent of Correct Responding on v-t and t-v Testing. (Bar graphs represent mean percent scores for groups 1 and 2. Data points represent individual subject data.)

Five of the six subjects selected the correct object in one mode following presentation in another 100% of the time in both phases V and VI. One subject, Julie, achieved four of six (67%) correct in each phase. Her two incorrect responses were not consistently the same errors across phases. The results of phases V and VI are depicted in figure 10.

Reliability Data

Reliability data were collected for Julie, Margie, and Bob. Reliability figures were 100%, 99.3%, and 100%, respectively. The mean reliability for Experiment III was therefore 99.8%.

Discussion

Experiment II demonstrated that subjects did not show evidence of equivalence for objects with distinctive visual and tactual features. The major finding of Experiment III was that if a subject is taught to match the visual presentation of such objects with symbols and to match the tactual presentation of the same objects with the same symbols, s/he could then select the objects visually when presented with them tactually and vice
versa. Therefore, even if visual-tactual stimulus equivalence was disrupted by distinctive features, the establishment of equivalence is still possible through experience with a paradigm like the Sidman stimulus equivalence paradigm used in this experiment.

In Phase III it was noted that subjects who were exposed to the tactual object presentation prior to the visual object presentations (Phases III and IV before Phases I and II) did significantly better on the visual presentations. This finding can not be simply attributed to practice, since the subjects first exposed to the visual presentations did not do better on the subsequent tactual presentations. Other researchers have found that when using the same objects, subjects do significantly better on visual discrimination tasks after exposure to tactual discrimination tasks than vice versa (Garvill & Molander, 1968; 1971).

One possible explanation for this phenomenon is that subjects may covertly see the objects as they haptically inspect them (Pick, 1974; Worchel, 1951). This covert visual behavior may then aid recognition when the object is later presented visually since they have "seen" that object before. Such imagery is presented only as a possible explanation; this experiment did not investigate covert visual behavior.
GENERAL DISCUSSION

Experiment I demonstrated that equivalence relations between a tactual stimulus and a visual stimulus from the same novel object are present to some extent without training the prerequisite conditional relations usually required to form equivalent stimulus classes. Thus, the human behavior repertoire includes tactual-visual equivalence or the potential for exhibiting tactual-visual matching to sample. Previous studies of tactual-visual equivalence have demonstrated conditional discriminations between tactual and visual stimuli and have often referred to such demonstrations as matching to sample or equivalence (Jones, 1981). According to Sidman however, a conditional discrimination does not in itself indicate equivalence. It shows only that a subject can pick a certain object when shown another. When such correct conditional discriminations are contingently reinforced, one can even say that the discriminations were trained directly. Direct training of tactual visual conditional discrimination does not allow one to separate functional equivalence from the discrimination that was taught. Sidman's (1971; 1972) paradigm provides a unique contribution in its ability to separate out and demonstrate equivalent stimulus classes; such was accomplished with visual and tactual stimuli in this experiment.

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The notion of a preexistent equivalence between tactual and visual stimulation is a difficult notion to account for behaviorally. It is possible that topographical features of the stimuli include enough characteristics common to tactual and visual perception that the aspects of the stimuli being responded to are actually the same, and therefore no functional difference in the stimuli exist. Thus, in Experiment I the subjects were simply shown the "same" stimuli when asked to choose a symbol the second time. If this is true, the results are neither surprising or difficult to account for. Whether a preexistent repertoire, common topographical features, or some other variable accounts for the equivalence relations seen cannot be decided on the basis of the research reported here. Further research needs to evaluate whether the equivalence relations would emerge as they did in this experiment if a stimulus does not look like it feels. If so, controlling variables other than common features would need to be discovered or a preexisting repertoire must be operationally defined and demonstrated in some way.

Experiment II provided evidence that relations between visual and tactual stimuli can be easily, and in this case, completely disrupted. At least, this is apparently the case. Sidman, Kirk, and Wilson-Morris (1985) studied the establishment of six member stimulus
classes. In previous studies (Sidman & Tailby, 1982) Sidman found that three member classes emerged immediately after training two of the three conditional discriminations and testing the third. In the six member classes, however, he found that matching to sample did not always occur on the first test, but that it did emerge with continued unreinforced testing. Therefore, it may be possible that if testing of the visual-tactual conditional relation is repeated many times the relations would emerge, or in the case of Experiment I, be strengthened. Such an event would indicate that repeated testing is not only necessary for large numbers of stimuli as Sidman has shown, but also for other variables that might deem a set of stimuli more complex. If complexity, not just number, is critical, then other variables need to be systematically examined. For example, in Sidman's subject of study, verbal behavior, one might study grammatical constructions, sentences, or rules.

One factor that would confound such emergence through testing in the tactual and visual experiments described in this study, is that continued testing also means continued exposure and study of the objects. Under the mand characteristics of the testing situation and the rule that the job is to pick the correct match, such continued study of the stimuli seems likely.
Instructional control, including mand characteristics and rules, has been shown to influence the behavior of subjects to comply with the instructions, often even if the contingencies or effort requirements would dictate very different responding (Baron, Kaufman, & Stauber, 1969; Galizio, 1979; Kaufman, Baron, & Kopp, 1966).

Experiment III demonstrated that subjects could match modality distinctive visual and tactual stimuli if they had previously been taught conditional discriminations between each of the stimuli and another stimulus. This experiment has therefore shown that the preexisting equivalence or the topographical features that may have controlled the matching seen in Experiment I is a sufficient, but not a necessary condition for tactual-visual equivalence. Tactual-visual equivalence can also be established through the formation of a three member stimulus class by utilizing a third stimulus in a transitivity training paradigm. While continued testing may have resulted in the emergence of conditional relations in Experiment II, this experiment indicated that no additional testing is required if the prerequisite conditional discriminations of the transitivity paradigm have been accomplished. Such immediate emergence of equivalence relations is in agreement with Sidman and Tailby's (1982) findings for three member stimulus classes.
Some researchers have postulated that tactual-visual equivalence may be mediated by verbal behavior in the form of rules or descriptions of the stimuli (Garvill & Molander, 1971; Gaydos, 1956; Koen, 1971). Anecdotally, four of the six subjects of Experiment III described a rule. When asked at the end of the experiment how she was deciding which object to select, one subject stated, "the two paired with blue go together, and the two with red go together, and so on." It is not clear whether these rules were the basis of selection or if the selection was the basis for the development of the rules. What is important is that two of the six subjects did not describe a rule related to color. One responded to the question with the statement, "It just seemed right." Although this is anecdotal and was not the focus of study, it indicates that verbal rules are not necessary to establish equivalence. Related to this is Sidman's finding that one subject who was able to demonstrate a three member equivalence relation was not able to name the stimuli (Sidman & Tailby, 1985). Sidman concluded that naming is not necessary for stimulus class formation. While Sidman's finding regarding the role of verbal behavior is supportive of the anecdotal data of this study, it deals more with the role of tacting than with rules. In general, verbal behavior by the subject about the task does not seem to be critical to the
establishment of stimulus equivalence.

Another possible role of verbal behavior in tactual-visual equivalence, however, involves a more direct use of tacting. It is possible that three member stimulus classes could include a visual stimulus, a tactual stimulus, and a word. That word could be the name of the object, a tact. If a person sees an object, such as a leaf, and calls it a leaf and later touches an object and calls it a leaf, then two conditional discriminations have been formed. From these two conditional relations with the one common stimulus, an equivalence of the tactual and visual perceptions of the leaf should emerge. Unlike previous studies which have utilized post test interviews to assess verbal behavior (Koen, 1971) or trained only conditional discriminations (Gaydos, 1956) this study provided more direct evidence of how verbal behavior could function in the establishment of equivalent relations between visual and tactual stimuli. The critical evidence is that the subjects were unable to discriminate the tactual and visual stimuli in Experiment II, yet after training symmetric relationships between each stimulus and a symbol the matching was possible. While no vocal or alphabet-based names were used, pointing to the symbol in this study could be considered a verbal response (a tact) since the response was initially taught using mediated contingencies (social
reinforcement) and the response form is controlled by a nonverbal stimulus (Peterson, 1978; Skinner, 1957).

As discussed in the introduction, traditional theories of tactual-visual equivalence implicated neurological mechanisms, topographical features, contiguous contact, and verbal mediation as methods by which equivalence is established. While this research does not provide definitive answers as to the origins of the relations, it presented another method of examining equivalence; one which, according to current research in experimental behavior analysis, is the only way to truly demonstrate equivalence. It also demonstrated that it is not likely that equivalence is a result of only one postulated mechanism since it was shown to "preexist" in one case and to be developed by training of transitivity relationships in another. Further research is needed to define and study the different variables and their interactions that affect the establishment of tactual-visual equivalence.

This research has also expanded the realm of study of the stimulus equivalence paradigm. Stimulus equivalence via transitivity has previously been studied only in the realm of verbal behavior. This study expands the application of principles related to equivalence to another area of behavior. Therefore, transitivity has been applied to mathematics, verbal behavior and, just
initially, to visual-tactual behavior. While continued study of verbal, visual, and tactual equivalence behavior is critical since more questions than answers have been raised, expansion of the empirical study of the paradigm to other areas of equivalence behavior may provide further information about variables effecting the establishment or functioning of stimulus classes as well as providing a better understanding of the variables controlling other equivalence behaviors.
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