# NOVEL PERFORMANCES VIA EQUIVALENCE RELATIONS

BY
© Copyright SCOTT THOMPSON

Accepted in partial fulfilment of the requirements for
the degree of MASTER OF SCIENCE
Saint Mary's University
Halifax, Nova Scotia
Canada

Approved: ______________________
(Thesis Supervisor)

Approved: ______________________
(Committee Member)

Approved: ______________________
(Committee Member)

ISBN 0-315-74447-2

# NOVEL PERFORMANCES VIA EQUIVALENCE RELATIONS

©Scott Thompson
Saint Mary's University
April
1992

## ACKNOWLEDGEMENTS

I wish to thank Dr. Linda Hayes for her advice, guidance and support in starting this project and Dr. Vic Catano for his quick feedback and scholarly advice in finishing this project.

I would also like to thank the other members of my committee, Dr. A. Cohen, for her insightful feedback, Dr. K. Hill, and Dr. G. Pretty.

TABLE OF CONTENTS

## INDEX TO TABLES AND FIGURES

## Introduction

The focus of this study was to investigate whether verbal description of behavior performances provided a basis for nonverbal action of behavior performances. The verbal description was "how to play the keyboard". The nonverbal behavior was playing the keyboard. Did expressing how to play the keyboard facilitate playing the keyboard? Which repertoire, playing the keyboard, or describing playing, is more available?

Learning verbal descriptions to perform behavior, then attempting the behavior is not unique. What is unique about the present study is how verbal descriptions were learned, through stimulus equivalence class paradigms. Learning through such a paradigm allows a shorter learning time of the description. This occurs because of its design; the equivalence class paradigm does not require training, or learned associations, between all the stimuli. Depending upon the design, certain associations will emerge without training, without being explicitly learned. This decreases learning time.

Another focus of the study was to investigate how much verbal description is necessary for efficient playing of the keyboard. Stimulus equivalence class paradigms place stimuli in relation, relations that may describe a behavior, for example. These stimuli may or may not be named. How does naming stimuli to describe performance affect performance?

Presented first are theoretical and operational definitions of the associations that comprise equivalence class paradigms: reflexive, symmetrical were able to form equivalence relations with specific keys on the keyboard, their music notation counter-parts, the corresponding letter names, and specific fingers on the subjects' hand. Relations learned through phases 1, 2, and 3 served as the timing equivalence class. Relations learned through phases 4, 5, and 6 served as the placement equivalence class. In phase 7 subjects were presented with compound stimuli containing information from both classes, beat duration and key placement. These stimulus classes merged via the compound stimuli. Subjects were then able to play simple pitch sequences on the keyboard. In phase 8 subjects described the equivalence relations from both classes. Subjects were assigned to 6 experimental conditions. The Timing and Placement Training subjects participated in all phases. Timing Only Training subjects participated in phases 1, 2, 3 and 7. Placement Only Training subjects participated in phases 4, 5, 6, and 7. Timing Only and Placement Only subjects were not able to play accurately the keyboard, since they were not exposed to all the necessary rules or instructions. No Timing Names subjects participated in phases 1 to 7, but did not receive training with the names (words) of the timing equivalence paradigm. No Placement Names participated in phases 1 to 7, but did not receive training with the names (letters) of the placement equivalence paradigm. No Names subjects participated in phases 1 to 7, but received no training with either sets of names. Naming the stimuli in the equivalence classes did not seem to have any measurable impact on keyboard playing. Describing keyboard playing emerged more reliably than playing the keyboard. Stimulus equivalence paradigms may be incorporated into teaching strategies. The current study demonstrates one such approach.

**Abstract**

Novel Performances via Equivalence Relations

By

Scott Thompson

April, 1992

The present study investigated the emergence of untrained novel behavior performances (keyboard playing) through teaching description (describing keyboard playing) of behavior performances. These descriptions provided subjects the following information: which key to press on the keyboard, with which finger to press the key, and how long to press the key. This information was conveyed through a musical staff with accompanying musical notation. Eighteen undergraduate subjects learned these descriptions of keyboard playing through stimulus equivalence procedures. Stimulus equivalence suggests different specific stimuli may occasion similar responses. Stimuli are said to function equivalently. Different stimuli that function equivalently are referred to as equivalence relations. Learning through stimulus equivalence paradigms does not require subjects to directly associate all stimuli for equivalencies to occur. Certain equivalencies emerged in the present study without direct stimulus-stimulus association. These equivalencies served as part of the description of keyboard playing. There were in 8 phases in the study. In phases 1, 2, and 3, subjects were able to form equivalence relations with relative time units (musically referred to as beats), their music notation counter-parts and corresponding words. In phases 4, 5, and 6 subjects

and transitive relations. Presented next are discussions of applications of such paradigms to verbal description, and application of that description to nonverbal behavior.

Stimulus Equivalence

Two or more stimuli become associated or paired, when the stimuli are in close temporal and/or spatial proximity over many interactions. The two stimuli, by way of their association, acquire functions of one another. *Stimulus equivalence* refers to the outcome of stimulus association. The associated stimuli are functionally equivalent, and conditionally specific. Stimulus equivalence paradigms are comprised of three associational relations: *reflexivity, symmetry*, and *transitivity* (Sidman & Osborne, 1973; Sidman, Osborne & Willson-Morris, 1974).

Reflexivity

The first equivalence relation is reflexivity. Conceptually stated, each stimulus involved in conditional relation(s) is also related conditionally to itself, that is stimulus A is the same as stimulus A. This is referred to as *identity matching* or reflexive discrimination. *Generalized identity matching* is reflexive discrimination with novel stimuli. Generalized identity matching or choosing two identical novel stimuli from a stimuli array has been shown with normal children and adults, (Dixon & Dixon, 1978; Lazar 1977; Sidman & Tailby, 1982; and Sidman et al., 1985) and with developmentally delayed adolescents (Sidman, 1971; Sidman & Cresson, 1973; Sidman & Cresson, 1974; Spradlin, Cotter &

Baxley, 1973; and Stromer & Osborne, 1982.)

Operationally defined, testing and training for reflexivity is accomplished through a *matching-to-sample (MTS)* procedure. In a MTS procedure subjects are presented with a *sample* stimulus and then various *comparison* stimuli. Comparisons may be presented simultaneously or successively. Subjects select a comparison upon being exposed to the sample via a variety of procedures, for example pointing or touching the comparison, placing an "X" on picture comparisons, verbalizing the comparison. Comparison selection depends on experimental design, stimulus modality and nature, and subject characteristics. If a relation is being *trained*, then reinforcement or feedback occurs after comparison selection. Reinforcement is usually a token, points or money. Feedback is usually red and green lights. A green light indicates the response is correct, a red light indicates the response is incorrect. If a relation is being *tested*, subjects select a comparison stimulus with no reinforcement or feedback.

When reflexivity is tested with humans, very often it is with children or developmentally delayed persons (Sidman, 1971; Sidman & Cresson, 1973; Spradlin, Cotter & Baxley,1973; and Stromer & Osborne, 1982). Rarely does research with normal adults train/test for reflexivity (Lazar, Davis-Long & Sanchez, 1984; Wulfert & Hayes, 1988; and Wetherby, Karlan & Spradlin, 1983). The suggestion is reflexivity must first occur in order for a more complex relation, namely symmetry, to occur. Since language is largely symmetrical responding and discrimination, reflexivity is assumed in normal adults with language. In keeping with this, reflexivity was not tested in this study.

In reflexive relations in the natural environment, the sample and comparison are the same stimulus. Simply put, stimuli function equivalently because they are equivalent (i.e. they are the same stimuli). Symmetrical relations explain how dissimilar stimuli function equivalently.

Symmetry

Conceptually, *symmetry* is two or more dissimilar stimuli that become associated. Through this association, these stimuli permit a common response. The process is as follows: given stimulus A has been associated with stimulus B in a particular context; B will now allow the same types of responses to occur as occurred to A (in that context). When this happens, the two stimuli are said to function equivalently (Sidman & Osborne, 1973; Sidman, Osborne & Willson-Morris, 1974).

For example, stimulus A is an object such as a tree. The object tree allows certain types of responses to occur, such as the smell of the sap, the sight of green leaves, the sound of the leaves rustling in the wind, the feel of the brittle bark, etc. Stimulus B may be the verbal label "tree". The verbal label in no way resembles the object tree. Stimulus A and stimulus B are dissimilar. However, the word "tree" may allow the same or similar responses to occur as an actual tree (i.e. the sight of green leaves, etc.). This pairing occurs when the two stimuli, the actual tree and the word tree, are in close temporal and/or spatial proximity over many interactions. Stimulus B allowing the same responses as A is termed *unidirectional association. Bidirectional association* is stimulus A allowing the same responses to occur as originally occurred to B, and B allowing the same responses as originally occurred to A. In the preceding example, as a result of the association of stimulus A and B, (AB; once two stimuli are associated, their relation is represented as one symbol) one might picture the word "tree" when confronted with an actual tree (Fields, Verhave & Fath, 1984; Sidman & Osborne, 1973; Sidman, Osborne & Willson-Morris, 1974). The bidirectional association (AB *and* BA, symbolized AB/BA) between two stimuli is the conceptual definition of *symmetry*, (Lazar, 1977; Sidman & Tailby, 1982; and Lazar, Davis-Long & Sanchez, 1984).

Operationally defined, symmetry is tested/trained through a MTS sample-comparison reversibility procedure (Sidman, Cresson & Willson-Morris, 1974; and Stromer & Osborne, 1982). Consider the research design for training/testing symmetry from Sidman et al. (1974). Two severely retarded subjects were trained to select comparisons from set B (lower case letters), given samples from set A (upper case letters). The subjects sat before a panel of nine translucent circular windows, arranged such that samples were presented in the centre window and eight windows around the sample presented the comparisons. After the sample stimulus (an upper-case letter) appeared, the remaining windows illuminated the comparisons, including the appropriate lower-case match. If the correct comparison was chosen, chimes would ring; if not, there were no chimes (the reinforcement). The selection response was pressing a comparison window.

All stimuli disappeared after a comparison choice was made. The presentations of comparisons and samples were random. This was the AB training. BA testing/training involves reversal: selecting comparisons from set A, given samples from set B. In Sidman's et al. (1974) procedure, presentation of the sample stimuli, upper-case letters, with the comparison stimuli, lower-case letters was reversed. Lower-case letters served as the samples and upper-case letters served as the comparisons in the BA training/testing. BA relations are most often tested first. If BA responding occurs then subjects are said to be responding symmetrically at that time. If BA responding does not occur, then BA training occurs. Once BA and AB responding achieves criterion through further training, then subjects are said to be responding symmetrically at that time. Symmetrical testing is operationally defined as sample-comparison reversibility using MTS procedures. Often, this procedure is termed *backward testing*. *Forward training* is the AB training.

Transitivity

Conceptually, transitivity is two or more dissimilar stimuli that become associated without direct training. Transitivity involves at least two conditional relations, such that two stimuli are not related to each other directly, but each stimulus is conditionally related to a common third stimulus. As a result of the common pairing, the two unrelated stimuli become paired. That is, given A choose B, given B choose A (AB symmetrical responding) and given A choose C, given C choose A (AC symmetrical responding). When given B as the sample there will be a tendency to choose C, (transitive responding); CB will emerge too. CB/BC are referred to as the transitive relations (Sidman, Cresson & Willson-Morris, 1974; Sidman & Osborne, 1973; and Stromer & Osborne, 1982). This occurs despite the fact that these stimuli have never been paired directly. Operationally, the research designs are typically: AB and AC are trained; BA and CA are tested and/or trained; and BC/CB are tested. All relations are tested/trained in a MTS procedure. This paradigm is referred to as the *transitive paradigm* or the *stimulus equivalence paradigm*. Since all the stimuli are argued to be operating equivalently, the stimuli are referred to as a *stimulus equivalence class*. Transitivity may be thought of as the most complex of the equivalence relations; that is first reflexivity must occur so that symmetry can occur, symmetry must occur so that transitivity can occur. A stimulus equivalence class is composed of all these relations: reflexivity, symmetry and transitivity.

On the Practical Significance of Transitivity. The emergence of transitive relations is significant because of the savings it affords in training. Consider the point made by Fields, Verhave & Fath (1984). If there are three stimuli, (i.e. A, B, and C) and two training pairs, (AB and AC) there is one transitive relation, (BC). If there are 16 stimuli and 15 training pairs, depending upon the stimuli arrangement, there are a possible 105 transitive relations! Current investigations have explored 15 training pairs with 60 emergent relations (Sidman et. al., 1985), and 18 training pairs with 112 emergent relations (Saunders, Saunders & Spradlin 1990). Transitive designs can be an extremely efficient method of teaching relations, especially for retardates or children.

Consider too, the point by Saunders et al. (1990). An adult male with a mild mental handicap was able to derive 112 relations among arbitrary stimuli, having been trained/tested three years earlier. This occurred in the absence of additional practising and/or training. Green, Mackay, McIlvane, Saunders and Socraci (1990) explain: a 3-member equivalence class involves the following relations: AB, AC, and BC, and their symmetrical counterparts for a total of six relations. If only two of the six relations remain undisturbed, the remaining can be derived. Several different combinations could suffice: CA and CB, etc. Extend this logic to 4-member classes, and only 3 relations must remain to derive 12 possible relations, etc. Equivalence relations seem to be stable in the long-term.

Receptive and expressive transitivity. Sidman et al. (1974) and Wetherby et al. (1983) describe *receptive* and *expressive* transitivity. Conceptually, if responding occurs largely through receptive channels (i.e. pointing), the relation is receptive. If responding occurs through expressive channels (i.e. verbalizing) then the relation is expressive.

Operationally defined, receptive transitivity refers to probing for transitive relations largely occurring through receptive channels, using the MTS procedure. Sidman et al. (1974) used visual pictures, for example a picture of a cat, as the common stimulus. The auditory names (the spoken word "cat") dictated to the subject were trained with the pictures (AB relations). Then the pictures were trained with the printed word "cat" (AC relation). This arrangement implied that the choice of the comparisons was receptive; that is pointing to a printed word or indicating which spoken word was associated with the visual picture. The subjects did not have to actively print or say the word.

Sidman et al. (1974) operationally defined *expressive transitivity* as pictures being trained with oral names spoken by subjects (AB relations). Then pictures were trained with printed words (AC relations). The transitive relations allowed the subject to say a word, for example "cat" when seeing the printed word *cat*. The choice of the comparison stimulus occurred through *expressive channels*. The response defines whether the mode is expressive or receptive Most experimental designs involve receptive transitivity. This is an important point since receptive transitive relations, as articulated by Sidman et al. (1974), only allow the subject to make a pointing response, a response that may not be particularly useful. Guess & Baer (1973) investigated the generalization from receptive responding to expressive language production in retardates. No generalization occurred. However, expressive language training did generalize to expressive responding. "It was concluded that automatic generalization between receptive and productive language is not necessarily an inevitable result of langauge training in such [developmentally delayed] subjects." (Guess & Bear, 1973, p.311). Expressive transitivity allows the person to label objects, often a very useful behavior. The current study investigated both receptive transitivity (playing the keyboard) and expressive transitivity (describing playing).

Stimulus Equivalence as the Basis for the Emergence of Other Behavior

Very little work in the area of stimulus equivalence has been applied to learning useful descriptions of behaviors. However, there are some applications of equivalence paradigms. The resultant new behaviors are usually rudimentary reading, spelling and counting. The subjects are able to say words for example "cat", or "dog" in the presence of the object or representation. Most of the applied work has used children or subjects with developmental disabilities (Gast, VanBiervliet, & Spradlin, 1979; Hollis, Fulton, & Larson 1986; Innocenti, Fiechtl & Rule, 1987; Mackay & Sidman, 1984; Mackay, 1985; Mackay & Ratti, 1990; McConagh, McIlvane & Stoddard, 1984; Sidman & Kirk, 1986; Spradlin & Saunders, 1986; VanBiervliet, 1977). These behaviors are useful, although the response is largely verbal. The Sidman et al. (1974) and Sidman & Cresson (1973) studies involved simple reading skills. The developmentally delayed subjects were able to speak words, for example *ear*, *cow*, or *man* in the presence of those objects. Innocenti et al. (1987) compared a traditional approach of teaching numbers to children, (the flash-card approach) with a transitive paradigm approach. The children from both approaches were able verbally to label the symbols (i.e. say "one" in the presence of "1" and vice versa) at the end of training. The children that learned through the transitive approach took fewer trials in total to learn the numerical equivalences. A two-month follow-up revealed that the transitive numerical equivalences were maintained.

What is learned are relations among stimuli that permit labelling responses. In addition, labelling always involves the training stimuli. For purposes of scientific rigor, the training stimuli are often arbitrary. Equivalence as "knowledge" of relations has not been demonstrated as a means by which action based upon that knowledge may emerge without training.

Labelling responses of arbitrary experimental stimuli are not particularly useful from an operant behavior standpoint since objects have no natural environmental referent (Lazar, 1977; Lazar et al., 1984; Sidman et al., 1982; Sidman et al., 1985; Sidman & Tailby, 1982; Spradlin et al., 1973; Stromer & Osborne, 1982; Touchette,1971; and Whetherby et al., 1983; Wulfert & Hayes, 1988). For example, the transitive responses in the Lazar (1977) study were nonverbal and receptive: pointing to two comparison triangles in different positions from the sample triangle. Triangles placed in such positions are unlikely to be found in the natural environment. Moreover, Lazar's study did not demonstrate transitive responding. As Wulfert & Hayes (1988) point out, the experimental design was flawed. The subjects were responding sequentially.

The receptive transitive responses in the study by Touchette (1971) were made by pressing comparison stimuli buttons. The arbitrary comparison stimuli (black figures) were the same as the samples, differing only in colour. The subjects had to discriminate on colour. Spradlin et al. (1973), Stromer & Osborne (1982) and Wetherby et al. (1983) required receptive transitive pointing responses to arbitrary stimuli. Sidman et al. (1982) found symmetrical responding occurred in children, but the response was receptive (i.e. key pressing) and the stimuli were Greek letters.

Lazar et al. (1984) discovered purely visual equivalence classes can be formed by children. All the sample and comparison stimuli were arbitrary symbols; the receptive transitive responses were pointing to symbols. From a theoretical perspective, it is useful to know stimulus equivalence classes need not be spoken labels for objects. However, pointing to arbitrary visual comparison stimuli with visual sample stimuli, is not practically useful. The stimuli are in relation, but without referents, and therefore of no use to the subjects.

Sidman & Tailby (1982) expanded the stimulus equivalence class design. They trained AB and AC with BC/CB emerging; then trained a novel stimulus D, with C. From this, subjects were able to demonstrate new transitive relations: DB/BD and AD/DA. Stimulus class expansion has been replicated: Sidman et al. (1985) increased the number of transitive relations even further. Sidman et al. (1985) trained separately two stimulus equivalence classes. The first class involved training AB and AC with BC/CB emerging. The second class involved training A'B' and A'C' with B'C'/C'B' emerging. AA' (the common stimuli in each class) were trained next. Sidman discovered all other relations emerged: AB', AC', A'B, A'C, BB', CC', C'B, and B'C. They concluded that two independently acquired stimulus equivalence classes can merge into one class on the basis of pairing the common stimuli in those classes.

Similar findings have been replicated by Saunders et al. (1988) and

Saunders, Watcher & Spradlin (1988). However, all transitive responding has been receptive and/or verbal.

Stimulus Relations as a Function of Context. Wulfert & Hayes (1988) presented interesting experimental evidence. They imposed a conditional context. Given the first context, stimulus A was paired with given stimuli; given the second context, stimulus A was paired with different stimuli. Different contexts were denoted by different colour buttons. Therefore, as the context changes, so do stimuli relations. This is important because in the natural environment contexts are dynamically changing, such that the nature and number of stimulus associations is always changing.

Conclusions

The results from these studies contribute to a behaviour-analytic model of concept formation. Stimulus equivalence classes can be formed by language-abled normal adults, children and mentally handicapped subjects. Equivalence classes can be formed using completely arbitrary stimuli, whether auditory, visual or cross-modal. Expansion of equivalence classes can significantly increase the number of transitive relations. Finally, equivalence classes are a function of the context.

Can equivalence classes serve as the basis for nonverbal operant behaviors? Can equivalence relations describe novel behavior? What effect does such training have on behavioral performance? The current study applied the stimulus equivalence paradigm to a nonverbal behavior, namely that of playing the keyboard in an attempt to answer these questions. Keyboard playing was chosen as the nonverbal behavior, but the focus of this investigation is the formation and application of equivalence classes.

Objective 1: The Nonverbal Action Based upon Equivalence Classes

The first objective of this study was to determine if stimulus equivalence paradigms could be used as a basis for the emergence of untrained nonverbal behavior with respect to stimuli involved in the equivalence classes.

The untrained novel behavior: playing the keyboard. The nonverbal responses were playing simple songs (pitch sequences) on a keyboard. These responses were chosen because keyboard playing is a useful operant behavior. Therefore, the responses are nonverbal implementations of stimulus equivalence classes. Keyboard playing requires responding to many relations simultaneously (i.e.: which key to play, how long to play the key, etc.). The subjects became actively involved in the responses.

This study investigated whether subjects could be taught to play the keyboard through stimulus equivalence paradigms. However, no explicit feedback was given for playing the keyboard (performing pitch sequences).

Selecting the Pitch Sequences (Melodies). Learning to play an instrument involves many aspects, among them learning to play a melody. Care must be given to which melody is selected to be the response. To help distinguish between different musical concepts, the following definitions from Feldstein (1985) are given to provide a basis for understanding the study.

| | |
|---|---|
| *tone*: | a pitch; a sound |
| *scale*: | the arrangement of notes [pitches] within a specific tonal setting |
| *interval*: | the distance between two pitches |
| *melody*: | single pitches sounded one after the other |

Using the production of simple pitch sequences as responses requires some caution. Pitch sequences were constructed so as not to sound too familiar. As Cuddy, Cohen & Miller (1979) have suggested, contextual conditions for melody placement may effect how a melody is perceived or recognized. One of the primary contextual conditions is music education, another is musical culture.

Music Education. Music education, more specifically the knowledge of musical rules affects melody recognition. (Cuddy, Cohen & Mewhort, 1981). Simply, the more exposure to music (listening and playing) a person has the more likely melodies will be recalled. According to Cuddy (1971) *untrained* music listeners tend to perceive single tones based upon pitch height only (how "high" or "low" a tone sounds). Untrained musical listeners tend not to perceive single tones with additional musical information. Cuddy, Cohen & Dewar (1978) also suggest untrained music listeners do not benefit from information in *relative judgement* (e.g.: identification of intervals).

Music Culture. Still, there are cultural musical rules concerning tones. Among them is tonality. Krumhansl (1983) offers an explanation of *tonality*:

> the perception of single pitches and relations between pitches are significantly altered by the tonal context. These alterations systematically reflect...tonal stability, which is central to the definition of tonal structure [tonality]. In a tonal system, one single pitch, called the tonic, is given particular emphasis and is the pitch around which the [musical] composition is organized. That single tone appears relatively frequentl2y, is rhythmically stressed, and tends to appear at the end of [musical] phrases. Every other pitch has a well defined relationship to the tonic with certain pitches more closely associated to the tonic than others. (p. 37).

Dewar, Cuddy & Mewhort (1977) discovered untrained music listeners do benefit from information regarding tone sequence. These listeners are able to distinguish whether a tone belongs in a sequence (a melody) based upon the cultural musical rule, that is tonality.

For these reasons the present study used naive music subjects and pitch sequences that attempted to avoid the establishment of a tonal pitch (tonality). This was facilitated by creating pitch sequences based upon the musical notes F, G, A, and B. A major scale is a specific arrangement of notes within a tonal setting. No major scale can be constructed starting on any of the F, G, A, and B notes with the notes F, G, A and B. Also, in the first, second, third and fifth pitch sequences used in testing for the final playing performances each note was presented with equal frequency (3 times). This occurred so as not to stress any particular note, and further attempt to avoid the establishment of a tonality. It was thought that tonal pitch sequences (melodies) may be easier to play on the keyboard, since subjects may respond to the cultural rule of tonality (pitch sequences may sound more familiar, and therefore "predictable") and not to the "instructions" (i.e. descriptions of keyboard playing) provided through the experiment. According to Cuddy, Cohen and Mewhort (1981) "Our account focuses on the role of structural rules [e.g.: tonality] and expectations that rules convey. Musical "form" is perceived when expectation is confirmed" (p.882).

It was useful, however, to obtain subjects that had some musical ability, so the Bentley Test of Musical Ability was used as a screening device. It was thought that subjects with a musical ability profile may have been more able to apply the musical instructions learned through the equivalence designs (simply, more able to play the keyboard). Subjects had to score 55% or better on the Bentley Test to continue the study. A cut-off of 55% was chosen to screen those subjects with limited musical ability. The Bentley Test of Musical Ability has four sub-tests: pitch discrimination, tonal memory, rhythmic memory, and chord analysis. The Bentley Test is reliable and valid (see Appendix B).

Playing the Keyboard. Playing the keyboard involves two aspects: which note to play (placement) and how long to play it (duration or beats). Musically, these are defined as:

*beat*: a relative unit of time used in music (i.e. 2 beats are exactly twice as long as 1 beat) *quarter beat*: 1 beat

*half beat*: 2 beats

*whole beat*: 4 beats

*note*: a symbol when placed on the music staff indicates which tone to play

*music staff*: a series of five parallel lines upon which notes are placed

*key*: a key on the keyboard

Beats can be named by printed words: quarter-beat, half-beat, whole-beat. Beats can be labelled by symbols. Beats may be expressed in auditory form as hearing one tone being twice as long as the previous (a 1-beat note followed by a 2-beat note). Beats expressed in an auditory form are the most difficult to learn because it is assumed subjects can respond *in relation* (i.e. there is no absolute time value for a whole-beat; it is four times as long in relation to the quarter beat). The training and testing for the timing components involved receptive responding; (i.e., pointing to musical symbols that matched auditory and written stimuli).

Placement relations require subjects to learn that a particular note on the musical staff indicates that a particular key must be played with a particular finger, called by a particular letter. The training/testing for the placement components involves receptive responding (i.e. pointing to positions on the musical staff that corresponded with keys, fingers, and letter names, as well playing a key on the keyboard).

Beats and placement components can be considered as two separate classes. In normal music training both are learned simultaneously as tested in the pre-test of this study. The two groups of equivalence relations (beat and placement components) were brought together during the testing phase, but not during training. This was accomplished by presentations of compound stimuli comprised of symbols representing beat and placement notes on the musical staff.

The nature of the playing performance. The playing performance depends on pressing a key to produce a sound to match a symbol. In training, subjects did not produce any sounds. They matched symbols to sounds via pointing. The production of sounds to symbols can occur since the sound and symbol relations are symmetrical.

Accurate keyboard playing also depends upon keys/fingers equivalences. This was not trained, nor is it explicitly conveyed in the compound stimuli. In training, both the keys and fingers were associated with notes on the musical staff. Because of this, the transitive responding of key/fingers is possible (i.e. playing a key with a particular finger).

Objective 2: The Merging of Equivalence Classes via Compound Stimuli

In most experimental designs with more than one stimulus equivalence paradigm, the common stimuli from each paradigm are paired, (Lazar et al., 1984; Sidman et al., 1985; and Wetherby et al., 1983). Other relations may emerge without training because of the association of the common stimuli. The current study investigated merging of two independently acquired stimulus classes by merging responding histories. Specifically, the first equivalence paradigm trained specific responses. The second paradigm also trained specific responses (using different stimuli). Then subjects were asked to respond simultaneously to both stimulus equivalence classes.

Specifically, keyboard playing requires dynamic responding with changing contextual conditions, beat (how long to press a key) and placement (which key to play) conditions. Each condition comprised a stimulus class and each stimulus class was trained independently. Compound stimuli, containing information from both stimulus classes (timing and placement), required simultaneous responding for accurate keyboard playing.

Objective 3: Naming Equivalence Class Members and Its Effect upon Nonverbal Performance Based upon Those Equivalence Classes

Naming is symmetrical responding to an object with a verbal label. Lazar et al. (1984) determined that equivalences occurred in the absence of labels. However, subjects imposed their own labels. Unexpectedly, the labelling schemes were sometimes inconsistent with the equivalence classes. This took place despite the accurate emergence of equivalence relations. Either naming does not have an effect upon formation of equivalence classes or it is unclear how the discriminations are being made.

Lazar, Davis-Lang & Sanchez (1984) discovered that equivalence class formation was not dependant upon stimulus modality or characteristics. They found equivalence classes could be formed with entirely visual and abstract symbolic stimuli. However, cross-modal (visual/auditory) stimulus classes develop more rapidly than purely visual classes in language-able subjects (Green, 1990; Sidman et al. 1986). This is not surprising. Our expressive language history is one of assigning spoken words (auditory) to objects (visual). This history begins early, from birth. Visual/visual equivalencies, such as word/symbol discriminations is not as extensive for most people.

Does naming stimuli in equivalence classes facilitate performance of novel behavior based on those equivalence classes? The present study investigated this issue by requiring some subjects to learn the names of both equivalence classes, some subjects to learn names of the first equivalence class, and some subjects to learn names of the second equivalence class. Some subjects learned neither equivalence class names. Which subjects would be best able to perform the novel behavior?

<u>Objective 4: To Determine Whether Keyboard Playing is any More or Less Available than Describing Playing</u>

In performing the pitch sequences there are both verbal (following a rule or instruction, referred to as rule-governed) and nonverbal (modifying responses as required to achieve the target response referred to as contingency-shaped) control (Hayes, Brownstein, Haas & Greenway 1986). Knowing, according to Skinner (1978, p.48, 73, & 104), is being able to express what the contingencies are required to perform a behavior; it is almost entirely verbal.

*Knowing* how does not easily translate into *doing* because of contingency-shaping elements. Since our verbal repertoire has an extensive history, saying how to do an activity is easy for most; for example, describing how to play the keyboard. There is no extensive history when performing a new behavior, as in playing the keyboard. The present study attempted to minimize the contingency component (i.e., the behavior to be performed with as little shaping as possible). Shaping refers to successive reinforcement of responding contingencies such that the responding becomes closer and closer to the target response. Therefore, it was speculated that the final playing performances would be more efficient in the verbal than the nonverbal form. It should be stressed that determining whether playing or describing playing is not an absolute comparison. Subjects were untrained with respect to keyboard playing. Subjects were language-able undergraduate university students with no observable language deficits, although subjects were untrained with respect to the specific musical verbal stimuli used in the investigation.

## Summary of Objectives

Objective 1 is that nonverbal action could be based upon equivalence classes. It was hypothesized that subjects would be able to perform pitch sequences on the synthesizer keyboard as a result of training in beat and placement equivalence paradigms. Objective 2 is that the merging of equivalence classes would occur via compound stimuli. It was hypothesized that responding to beat and placement paradigms would merge (via the compound stimuli) to allow accurate keyboard playing and describing playing. Objective 3 is to investigate the role of naming equivalence class members and its effect upon nonverbal performances based upon those equivalence classes. Objective 4 is to determine whether keyboard playing is any more or less available than describing playing. It was hypothesized that describing keyboard playing would be a more available repertoire than keyboard playing.

## Method

Subjects and Conditions

Eighteen right-handed undergraduates of Saint Mary's University of both sexes volunteered for this study through in-class announcements and a sign up poster. They were offered $10.00 payment for participating in all sessions. All subjects participated in at least three sessions. During the first session, pre-tests of keyboard playing and of all the equivalence relations occurred as described below. During the final session, the post-test of keyboard playing and describing playing occurred. Between these two sessions, training and testing on the equivalence relations occurred. A variable number of sessions occurred in between the first and final session depending upon the number of training trials required for individual subjects to reach criterion on the discriminative relations. Subjects were randomly assigned to one of six conditions: Timing and Placement Training (N=5), Timing Only Training (N=2), Placement Only training (N=2), No Timing Names (N=3), No Placement Names (N=3), and No Names (N=3). Subjects in Timing Only Training and Placement Only Training participated in 1 session; all others participated in 3 sessions. The experimenter explained that participation required several sessions and that the area of investigation was music. No other details of the experiment were provided.

Demographic data is presented in Table 1. There were 7 female and 11 male subjects; mean age was 25.8 years; range was 19 to 33 years. Twelve subjects had no music training at all. The remaining six subjects participated in school choirs or ukulele classes. Of these subjects there was never more than one assigned to any experimental condition, except for the Timing and Placement condition where there were two such subjects.

General Procedure

Subjects completed an informed consent form, (see Appendix A) then The Bentley Test of Musical Ability (see Appendix B) was administered and scored. If subjects scored higher than 55%, the procedure continued. All subjects were trained individually in several sessions. Each session lasted approximately 60-75 minutes.

Table 1

Subject Demographic and Descriptive Information

| Subj. Group | Subj. No. | Sex | Age | Bentley Score | Musical History |
|---|---|---|---|---|---|
| Timing Place-Train-ing | 1 | male | 23 | 67% | none |
| | 2 | female | 23 | 70% | none |
| | 3 | male | 24 | 70% | elemtry school |
| | 4 | male | 23 | 76% | none |
| | 5 | female | 19 | 55% | school/choir |
| No Timing Train | 6 | male | 24 | 60% | choir & ukulele |
| | 7 | male | 25 | 55% | none |
| No Place-ment Training | 8 | female | 24 | 56% | none |
| | 9 | female | 23 | 56% | none |
| No Timing Names | 10 | female | 21 | 76% | none |
| | 11 | female | 31 | 82% | choir |
| | 12 | male | 23 | 65% | none |
| No Place-ment Names | 13 | male | 33 | 80% | none |
| | 14 | male | 24 | 68% | ukulele |
| | 15 | male | 25 | 71% | none |
| No Names | 16 | female | 20 | 58% | none |
| | 17 | male | 32 | 65% | choir |
| | 18 | female | 22 | 70% | none |

Subjects were seated at a table in a small experimental room, before a synthesizer. On the synthesizer was placed a small panel with a red and green light. Subjects were given the following instructions: "You will first be presented with one item. This item serves as the sample. You will then be presented with three or four different items. These items serve as the comparisons. Point to the comparison that you think goes with the sample. Notice the red and green lights. During some phases one of the lights will be illuminated; green indicating that your choice was correct; red indicating that it was incorrect. Then another sample will be presented; it may be the same as the first or it may not. Select again a comparison. During other phases no lights will be illuminated. This process will continue until I indicate that it is time to stop. If you have any questions, please ask. Let us first try an example".

Pre-testing of keyboard playing and of all relations (to be trained) occurred before training. All training and testing used the MTS format. All correct training responses were reinforced with a green light; all incorrect training responses were extinguished with a red light. No feedback was given during testing. Criterion was the same for all training relations: 14 of 15 correct consecutive responses; an incorrect response reset the count to 0 correct responses. For testing symmetrical responding the criterion was 9 of 10 trials correct. If symmetrical responding was evident, subjects moved to the next phase. If not, subjects re-trained (with feedback) and were tested for symmetrical responding again. In each phase all forward relations were trained before testing of the backward relations. This occurred before movement into further phases.

Presentation of sample and comparison stimuli was random in all phases. There was a practice trial at the beginning of all sessions (both training and testing). All subjects followed the same sequence: timing equivalence training then placement equivalent training, then keyboard performance.

Reliability

All trials were recorded by the experimenter on data sheets as correct or incorrect. Data sheets are filed and retained. As well, the final keyboard playing responses were videotaped. Reliability checks of the videotapes were performed by an external person, unaware of the objectives of the study but cognizant of musical keyboard playing. Reliability on keyboard playing was calculated by dividing agreements in correct responding with respect to key, finger, and beat components, and dividing by agreements plus disagreements on these measures. Inter-observer-reliability was 95%.

Timing Equivalence Paradigm Stimulus Sets

The following sets of stimuli were used to establish the timing equivalence paradigm:

Stimulus set A (auditory beat patterns). Stimulus set A was auditory and consisted of the sound of the number of beats (i.e. 1, 2, or 4 beats). The numbers 1 to 4 were counted aloud in succession. Then, tones were presented with the numbers. Some tones were audible for the full count. Some were audible for the count of one number; some for the count of two numbers. The specific auditory beat patterns used are presented in Table 2.

The tones and numbers were recorded and then played to the subjects on cassette tape. The numbers were counted at the same speed and presented at the same volume. The tones were all the same pitch; that is middle "C". The tones were generated from a synthesizer. This was important since the sound did not decay according to the striking force of a player's hand.

Stimulus set B (visual beat patterns). Stimulus set B was visual; it consisted of the music symbols used to represent the beat sequences presented as stimulus set A. The stimuli were on 8' by 10' cards; symbols were in black ink (see Table 2).

Stimulus set C (printed words). Stimulus set C was visual; it consisted of printed word patterns describing the auditory beat patterns. The stimuli were on 8' by 10' cards; the word patterns were printed in black ink (see Table 2).

Placement Equivalence Paradigm Stimulus Sets

The following sets of stimuli were used to establish the placement equivalence paradigm:

Stimulus set D (staff placements). Stimulus set D was visual; it consisted of a parallel series of five lines (a music staff) and an "X" marked on the staff, either on a line or between two lines. Only four positions were used: two "X's" on spaces; two on lines. The stimuli were printed in black ink on 8' by 10' cards. The specific staff placements used are presented in Table 3.

Table 2

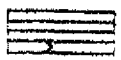
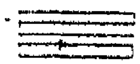
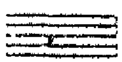
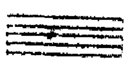
Stimuli Descriptions and Training Testing Sequences for The Timing Equivalence Paradigm

| Stimulus Name and Description | Stimulus Name and Description | Train | Test | Stimulus Name and Description | Train | Test | Transitive Test |
|---|---|---|---|---|---|---|---|
| A1: 1 tone: audible for the full count (1,2,3,4) | B1: symbol; 𝅝 | A1B1 | B1A1 | C1: 1 word; "whole-beat" | A1C1 | C1A1 | B1C1/C1B1 |
| A2: 2 tones; one audible for the count 1,2; the other for 3,4. | B2: symbol; 𝅗𝅥 𝅗𝅥 | A2B2 | B2A2 | C2: 2 words; "half-beat, half-beat" | A2C2 | C2A2 | B2C2/C2B2 |
| A3: 4 tones: each audible for one count | B3: symbol; ♩ ♩ ♩ ♩ | A3B3 | B3A3 | C3: 4 words; "quarter-beat, quarter-beat, quarter-beat, quarter-beat" | A3C3 | C3A3 | B3C3/C3B3 |
| A4: 3 tones; first 2 audible one count each (1,2), the third for two counts (3,4) | B4: symbol; ♩ ♩ 𝅗𝅥 | A4B4 | B4A4 | C4: 3 words; "quarter-beat, quarter-beat, half-beat" | A4C4 | C4A4 | B4C4/C4B4 |
| A5: 3 tones; first audible for two counts (1,2), last two for one count each (3,4) | B5: symbol; 𝅗𝅥 ♩ ♩ | A5B5 | B5A5 | C5: 3 words; "half-beat, quarter-beat, quarter-beat" | A5C5 | C5A5 | B5C5/C5B5 |
| A6: 3 tones; first audible for one count (1), the second for two counts (2,3), the third for one count (4) | B6: symbol; ♩ 𝅗𝅥 ♩ | A6B6 | B6A6 | C6: 3 words; "quarter-beat, half-beat, quarter beat" | A6C6 | C6A6 | B6C6/C6B6 |

Note. Transitive testing occurred after AB and AC training. Comparisons and samples for the transitive relations (BC/CB) were random.

Table 3

Stimuli Descriptions and Training/Testing Sequences for the Placement Equivalence Paradigm

| Stimulus Name/ Description | Stimulus Name/ Description | Train | Test | Stimulus Name/ Description | Train | Test | Stimulus Name/ Description | Train | Test | Transitive Test |
|---|---|---|---|---|---|---|---|---|---|---|
| D1: symbol:  | E1: "F" key on keyboard | D1E1 | E1D1 | F1: subjects' thumb | D1F1 | F1D1 | G1: the letter "F" | D1G1 | G1D1 | E1F1/F1E1 E1G1/G1E1 F1G1/G1F1 |
| D2: symbol:  | E2: "G" key on keyboard | D2E2 | E2D2 | F2: subjects' index finger | D2F2 | F2D2 | G2: the letter "G" | D2G2 | G2D2 | E2F2/F2E2 E2G2/G2E2 F2G2/G2F2 |
| D3: symbol:  | E3: "A" key on keyboard | D3E3 | E3D3 | F3: subjects' middle finger | D3F3 | F3D3 | G3: the letter "A" | D3G3 | G3D3 | E3F3/F3E3 E3G3/G3E3 F3G3/G3F3 |
| D4: symbol:  | E4: "B" key on keyboard | D4E4 | E4D4 | F4: subjects' ring finger | D4F4 | F4D4 | G4: the letter "B" | D4G4 | G4D4 | E4F4/F4E4 E4G4/G4E4 F4G4/G4F4 |

Note. Transitive testing occurred after DE, DF and DG training. Comparisons for the transitive relations (EF/FE, EG/GE, and FG/GF) were random.

Stimulus set E (keys). Stimulus set E was visual; it consisted of specific keys on the synthesizer. Only four keys were used, those that musically correspond with the staff placements presented in stimulus set D, (see Table 3).

Stimulus set F (fingers). Stimulus set F was visual; it consisted of the subjects' fingers on his/her right hand. The four fingers were the thumb, index, middle and ring fingers (see Table 3).

Stimulus set G (letters). Stimulus set G was visual; it consisted of the letters F, G, A and B (see Table 3).

The Compound Visual Stimuli (Visual Pitch Sequences) Used to Test Playing Performances. These compound visual stimuli (herein referred to as visual pitch sequences) were printed in black ink on 8' by 10' cards. Playing performances were testing by presenting each subject with a compound stimulus as presented in Table 4. The compound stimulus consisted of a music staff with representations of pitch patterns from stimulus set B, (see Table 4).

Timing Equivalence Paradigm Training Sequences

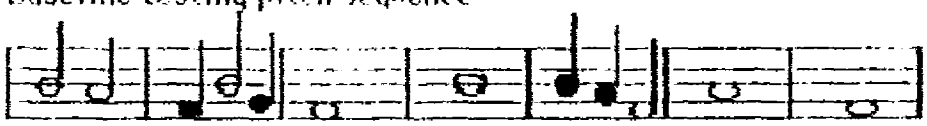
All subjects in this condition received training with the common stimulus set A, the auditory beat patterns. The training sequence consisted of three phases:

Phase 1. The first relations to be trained were the auditory beat patterns (stimulus set A) with the visual symbols (stimulus set B). During training sessions auditory beat patterns were samples and visual beat patterns were the comparisons (AB relations). Three comparisons, selected from stimulus set B,

**Table 4**

<u>**The Visual Pitch Sequences (Compound Stimuli) Used**</u>

Baseline testing pitch sequence



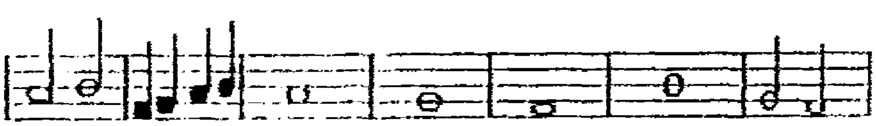
First pitch sequence tested after training

Second pitch sequence tested after training.

Third pitch sequence tested after training.

Fourth pitch sequence tested after training:

Fifth pitch sequence tested after training:



were presented for every sample. In all there were 12 comparison stimuli used: six stimuli that would be reinforced, given the correct sample; and 6 stimuli never reinforced. The comparison choice for training was pointing to a visual beat patterns. For symmetrical testing the comparison choice was verbally indicating the first, second or third auditory patterns (see Table 2).

Phase 2. The second relations to be trained were the auditory beat patterns (stimulus set A) with the printed words (stimulus set C). In training, auditory beat patterns served as sample stimuli and word beat patterns were comparisons (AC relations). Again, there were 12 comparison stimuli used: six stimuli that would be reinforced, given the correct sample; and 6 stimuli never reinforced. Training and testing responses were the same as Phase 1 until the criterion was achieved (see Table 2).

Phase 3. These relations were tested: visual symbols (stimulus set B) with printed word patterns (stimulus set C), and their symmetrical counter-parts were tested. For specific training/ testing sequences, see Table 2. The transitive relations, visual beat patterns/word beat patterns (BC/CB relations) were randomly tested for a total of 20 trials. Criterion transitive responding was 90% accuracy, if not then AB and AC relations were re-trained, BA and BC relations were re-tested. Then transitive responding was re-tested. The comparison choice was pointing to a symbol (CB relations) or to a word (BC relations).

Placement Equivalence Paradigm Training Sequences

All subjects in this condition received training with the common stimulus class D, staff placements. The training sequence consisted of four phases:

<u>Phase 4.</u> The first relations to be trained were the staff placements (stimulus set D) with the synthesizer keys (stimulus set E). First, staff placements (samples) and keys (comparisons) were trained (DE relations). Comparisons were always the same: 4 samples that would be reinforced, given the correct sample (4 white keys). All comparisons were present during each discrimination. The comparison choice response was pressing down on a key. Symmetrical comparison choices were pointing to a staff placement, (see Table 3).

<u>Phase 5.</u> Staff placements (stimulus set D) were trained with fingers (stimulus set F). Staff placements (samples) were trained with fingers (comparisons), the DF relations. There were 5 comparisons: 4 that would be reinforced, given the correct sample, and the "pinky" which was never reinforced. 8All comparisons were present during each discrimination. The comparison response was lifting a finger. Symmetrical comparison choices were pointing to a staff placement (see Table 3).

<u>Phase 6.</u> Staff placements (stimulus set D) were trained with letters (stimulus set G). Staff placements (samples) were trained with letter names (comparisons), the DG relations. There were only four comparisons; each to be reinforced depending upon the sample. The choice response was pointing to a letter name. Symmetrical testing occurred as above (see Table 3).

<u>Phase 7.</u> Transitive testing (forwa: d and backward) of the following

relations: keys with fingers (stimuli sets E and F); fingers with letters (stimuli sets F and G); and keys with letters (stimuli sets E and G), see Table 3. First, the keys/fingers (EF) transitive relations were tested. Response choices for keys/fingers relations were lifting a finger; for fingers/keys, pressing a key. Second, the keys/letters name (EG) transitive relations were tested. Response choices for keys/ letters were pointing to a letter; for letters/keys, pressing a key. Third, the keys/letters (EG) transitive relations were tested. Response choices for keys/letters relations were pointing to a letter name; for letter name/keys, pressing a key. All sample and comparisons were the same as in testing. Testing of all relations was random.

Testing of Keyboard Performances

Phase 8. Subjects were presented with visual pitch sequences and asked "play this pitch sequence as best you can, reading from left to right". The performances were videotaped. Subjects were presented with the visual pitch sequences (the compound stimuli), which they were asked to play. There were 5 visual pitch sequences, presented in the sam order for all the subjects (see Table 4).

The criterion performance was not more than 4 errors of any sort per pitch sequence. If more occurred, s/he was asked to try again. Any beat error was not using the correct beat duration. Any key error was not using the correct key; and any finger error was not using the correct finger. The performance errors were not relationally defined; for example, an error in the BA relation(s) (visual beat patterns with auditory beat patterns). This occurred because it is not possible to differentiate whether errors occurred in the "rule" (that is the association of the visual beat patterns with the auditory beat patterns or vice versa) or whether errors occurred in the application of the rule.

The subjects were allowed as many practice trials as necessary to reach the criterion of performance. All the subjects played the pitch sequences at approximately the same speed; a metronome was used to keep consistency between subjects. The speed used, 44 beats per minute (one quarter-note equalled one beat), was very slow.

Phase 9 Questionnaires were typed in black ink and presented on 8' by 11' paper. There were separate questionnaires for each visual pitch sequence. Questions were grouped together (i.e., all questions concerning beats were asked together, and for keys, fingers, and staff placements). Specifically, these questions were asked:

a) What is the letter name of the staff placement?

b) With which finger is appropriate to play the note?

c) Which key is appropriate to play this note?

d) How many beats does the note receive?

e) Is the note a quarter-note, half-note or a whole-note?

The Timing and Placement Training subjects written responses were recorded on questionnaires.

Experimental Design

Objective 1: The Nonverbal Action Based upon Equivalence Classes

Timing and Placement subjects (S1-S5) participated in all nine phases of the study. These subjects acquired the following information: how long to play (AB/BA relations) a specific key (DE/ED relations) with a specific finger (DF/FD relations). Also, the subjects could label tone duration (printed word beat patterns, stimulus set C); and name staff placements (letter names, stimulus set G). Subjects should have all knowledge required to play the keyboard.

Objective 2: The Merging of Stimulus Classes via Compound Stimuli

In phase 8, Timing and Placement subjects were presented with visual pitch sequences containing both beat pattern and placement information. Accurate keyboard playing depended upon simultaneous responding from both paradigms. The Timing Only subjects (S6 and S7) and Placement Only subjects (S8 and S9) were controls. These subjects received training in only one equivalence class (either timing or placement training). When keyboard playing was tested, the same visual pitch sequences were used as for all subjects. Since only one paradigm was trained, stimuli from each paradigm could not merge. If accurate keyboard playing emerged for Timing and Placement subjects, this would support the idea that performances depended upon merging of the two classes.

Objective 3: Naming Equivalence Class Members and Its Effect upon Nonverbal Performance Based upon Those Equivalence Classes

The Timing and Placement Training subjects were trained/tested on all relations, including names from both timing and placement paradigms. The No Timing Name subjects (S10-S12) did not receive training with the beat patterns words (or *names)*, stimulus set C. The No Placement Name subjects (S13-S15) did not receive training with the letters (or *names of placements)*, stimulus set G. Finally, the No Name subjects (S16-S18) did not receive training with either beat patterns or placement names. All other relations were trained/tested, as specified in the timing and placement equivalence training sequences.

An error-analysis of keyboard playing was conducted. Recorded errors in keyboard playing were: keys, fingers, and beat value. All subjects' errors were recorded. This permitted a comparison of keyboard playing by number of errors and trials to criterion of correct playing.

Objective 4: To Determine Whether Keyboard Playing is any More or Less Available than Describing Playing

An error analysis of describing playing was conducted for subjects *all names only*. Recorded errors in describing playing were: keys (DE relations), fingers (DF relations), placement names (DG relations), beat durations (AB relations) and word beat patterns (AC relations) If an error was committed in playing the keyboard, it was marked incorrect. Errors in playing and in describing playing were compared. There was an 88.88% error-free criterion of success. Describing playing had no criterion.

**Results**

The results of the study are organized according to each of the four main objectives. As Objective 1 and Objective 2 involve comparisons of timing and placement classes between subjects, the results pertaining to these two objectives are grouped together. Within each grouping, results related to both the acquisition of the equivalence class and keyboard playing are presented where appropriate.

Objective 1: The Nonverbal Action Based upon Equivalence Classes, and Objective 2: The Merging of Stimulus Classes via Compound Stimuli

Acquisition of Equivalence Classes

Timing and Placement Training (S1-S5). Results of equivalence training and testing for subjects involved in timing and placement training are presented in Figures 1 and 2. No subject showed evidence of equivalence relations in pre-testing. All subjects showed symmetrical responding for both timing and placement paradigms: BA relations (visual/auditory beat patterns), CA relations (word/auditory beat patterns), ED relations (keys/staff placements), FD relations (fingers/staff placements), and GD relations (letters/staff placements). All subjects demonstrated transitive responding: BC/CB relations (visual/word beat patterns), EF/FE relations (keys/fingers), FG/GF relations (fingers/letters), and GE/EG relations (letters/keys).

S1 failed to reach criterion for the placement transitive relations (EF/FE,

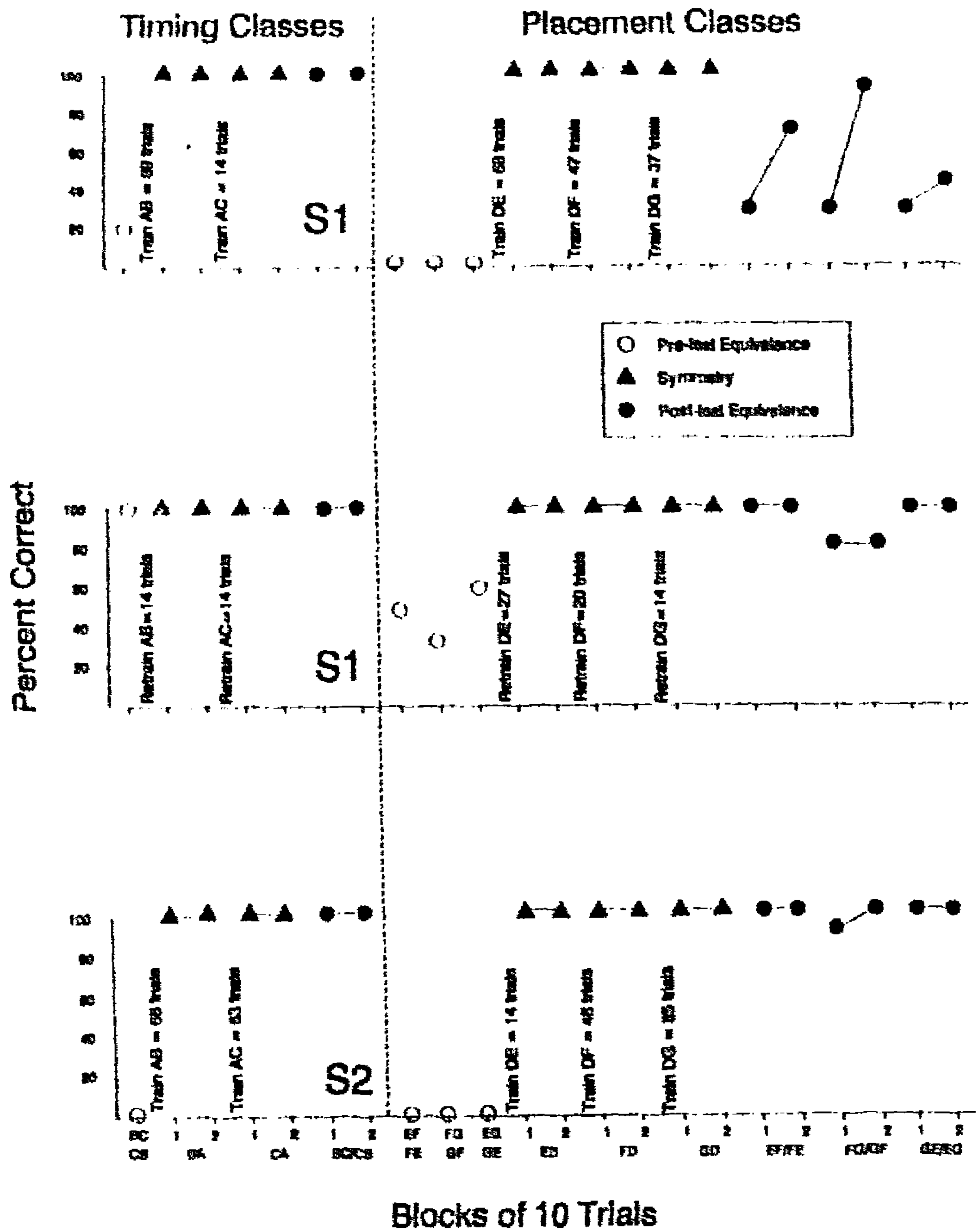



Figure 1. Individual training/testing data for Subjects 1 and 2 of the Timing and Placement Training group. Test data presented as percentages of trials correct (vertical axis) across blocks of 10 trials (horizontal axis). Numbers of training trials are presented in vertical text.

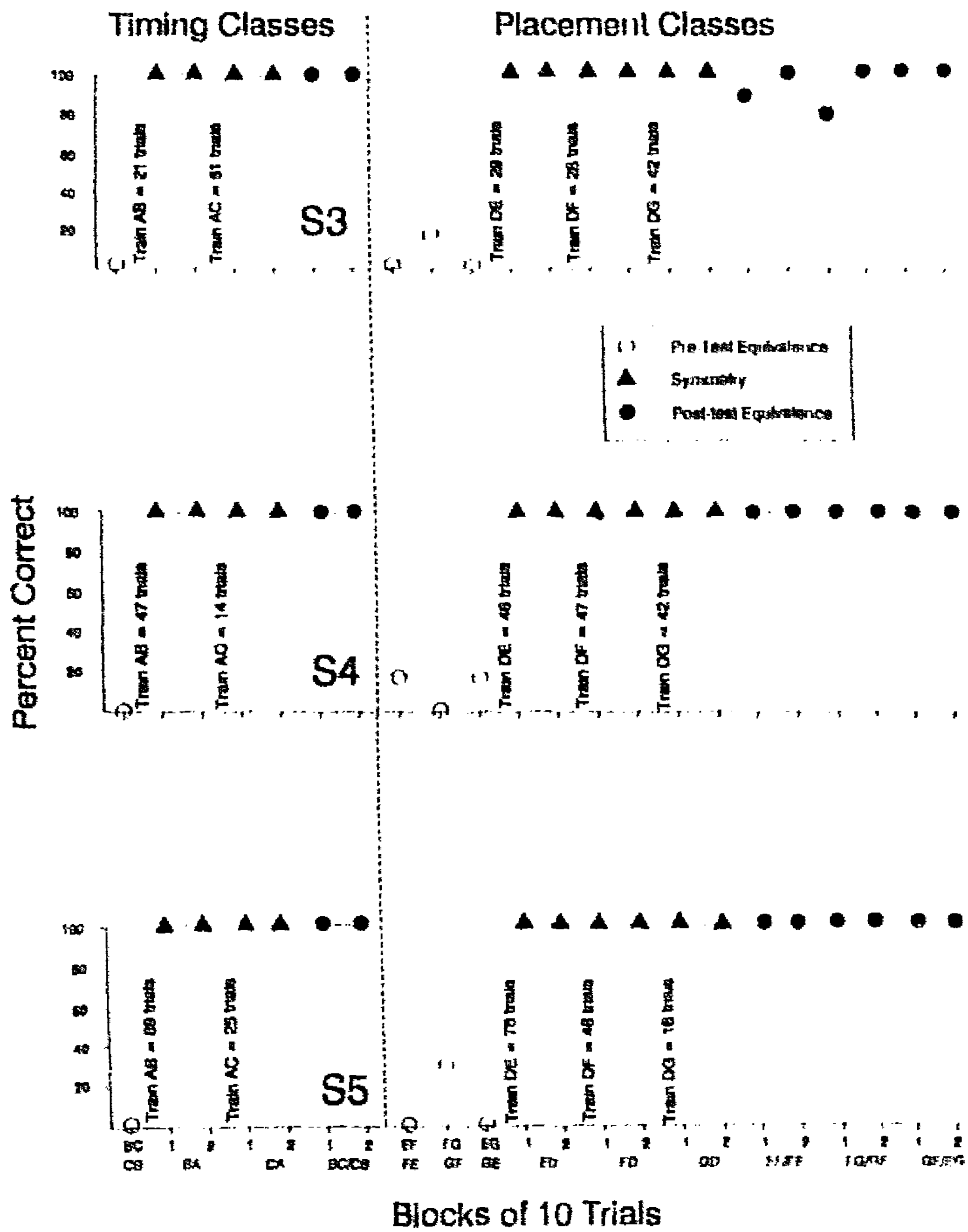



Figure 2. Individual training/testing data for Subjects 3 to 5 of the Timing and Placement Training group. Test data presented as percentages of trials correct (vertical axis) across blocks of 10 trials (horizontal axis). Numbers of training trials are presented in vertical text.

FG/GF and GE/EG). After re-training, S1 achieved criterion.

Timing Only Training (S6, S7) and Placement Only Training (S8 and S9). S6 and S7 displayed perfect symmetrical (BA, CA; symbol/auditory, and word/auditory beat patterns) and transitive (BC/CB, symbol/word beat patterns) responding for the timing paradigm, as shown in Figure 3. S6 required a considerable number of trials, 235, to reach criterion for the AB (auditory/symbol) relations. S8 and S9 acquired the symmetrical (ED, FD, GD; keys, fingers, and letters with staff placements) and transitive (EF/FE FG/GF GE/GE; keys/fingers, fingers/letters, and letters/keys), also shown in Figure 3.

Keyboard Playing

Pre-tests. None of the subjects showed correct beat, key, or finger selections in pre-tests of keyboard playing.

Timing and Placement Training Subjects. All Timing and Training subjects were able to perform the pitch sequences after equivalence training and testing. Figure 4 shows the trials to criterion for correct keyboard playing (< 5 errors per pitch sequence for beat, key and finger selections). Generally, the number of trials to criterion decreases across pitch sequences for all subjects. S1 required 5 trials to achieve criterion in the first pitch sequence, six for the second, three trials for the third and one trial for the fourth and fifth pitch sequences. S2 goes from 6 trials on the first pitch sequence decreasing to 3 on the final pitch sequence; S3 from 17 to 3; S4 from 3 to 2; and S5 from 10 to 2.

Timing Training Only Subjects (S6 and S7). Neither subject was able to

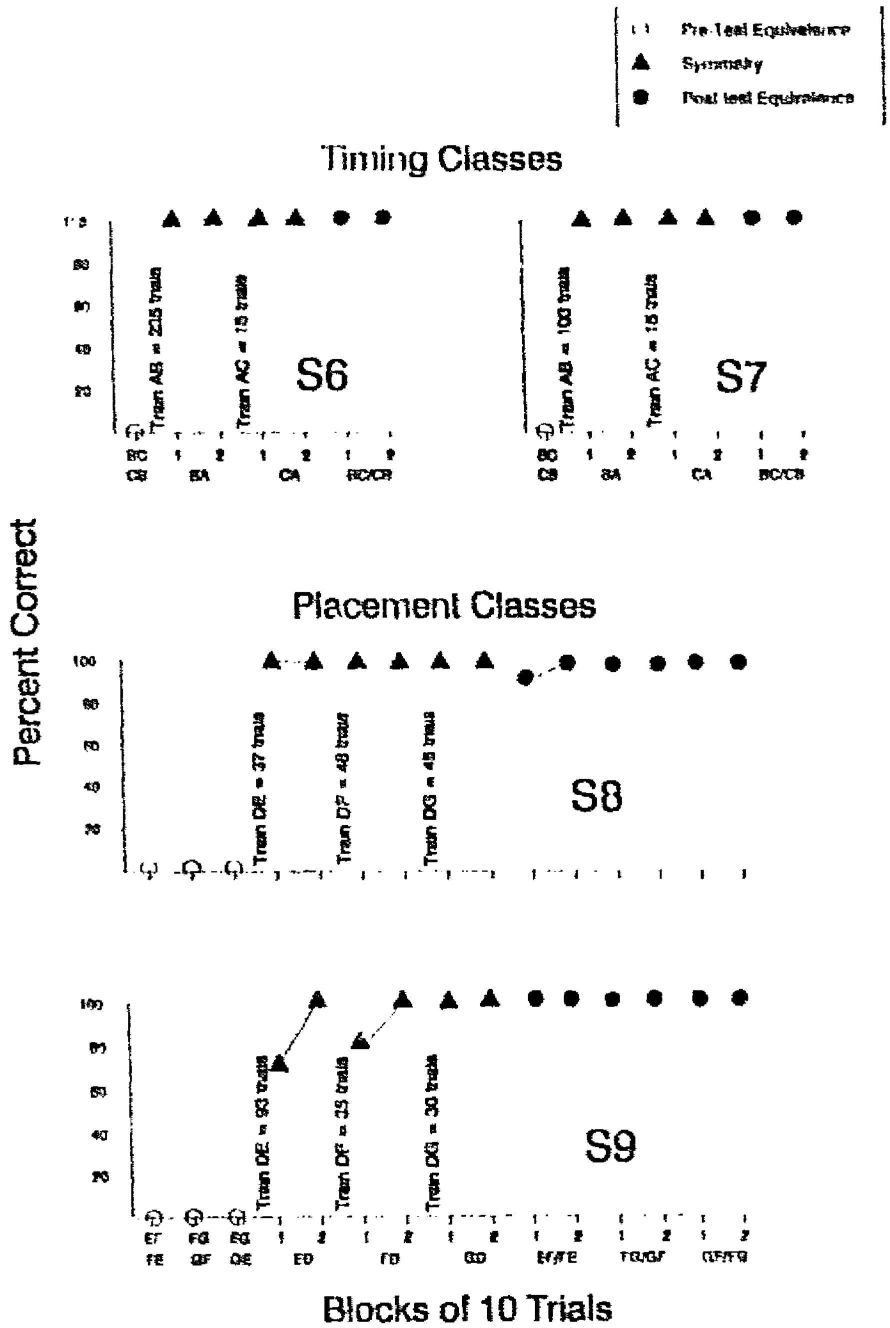



Figure 3. Individual training/testing data for Subjects 6 and 7 of the Timing Training Only group and Subjects 8 and 9 in the Placement Training Only group. Test data presented as percentages of trials correct (vertical axis) across blocks of 10 trials (horizontal axis). Numbers of training trials are presented in vertical text.

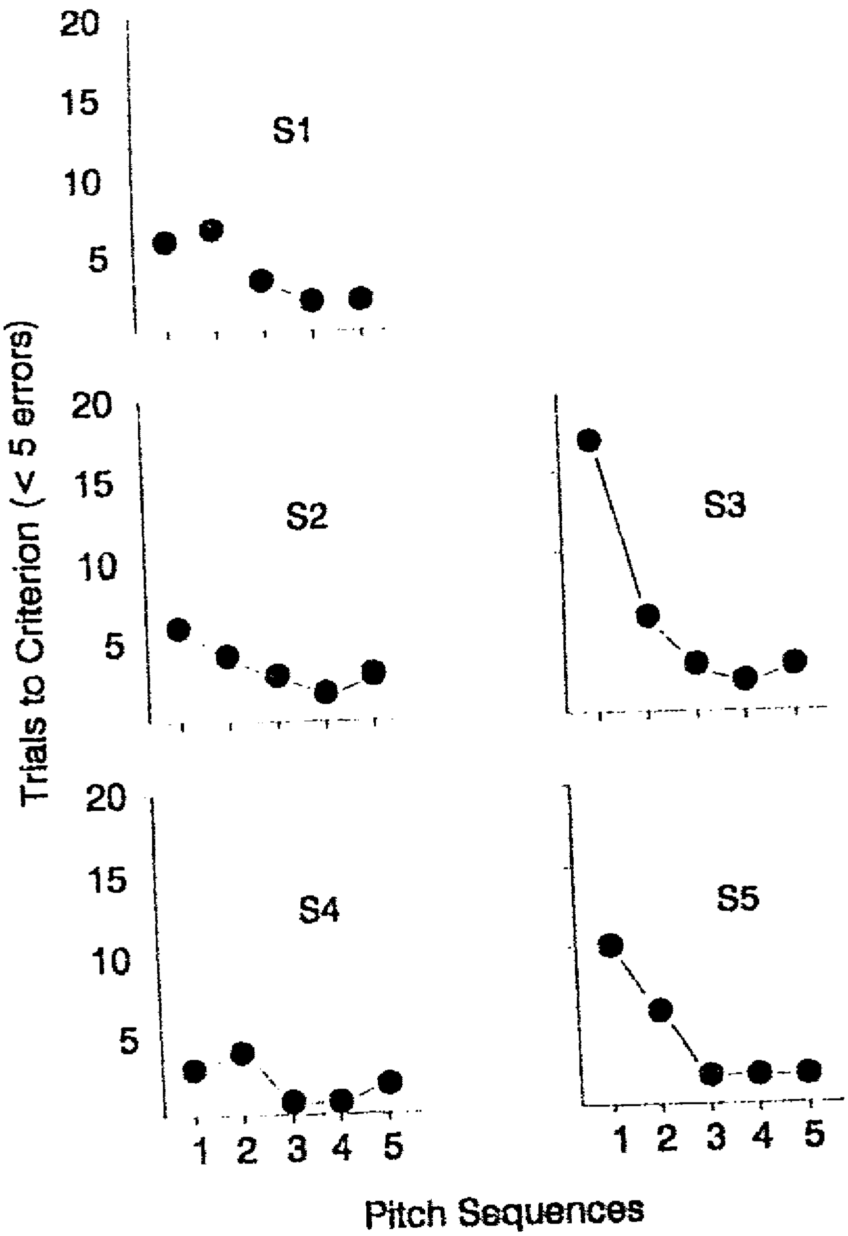



Figure 4. Trials to criterion (less than 5 errors) for each pitch sequence in the keyboard playing test for Subjects 1 to 5 in the Timing and Placement Training group.

play the keyboard. Subjects were able to respond accurately only with respect to timing relations. Specifically, subjects pressed any keys, with any fingers, but for correct durations.

Placement Training Only Subjects (S8 and S9). Subjects only responded accurately to trained/tested relations. Specifically, subjects pressed appropriate keys with fingers, but for incorrect durations.

Objective 3: Naming Equivalence Class Members and Its Effect upon Nonverbal Performance Based upon Those Equivalence Classes

Acquisition of Equivalence Classes

No Timing Names (S10-S12). Results of equivalence testing and training for these subjects are shown in Figure 5. Subjects acquired timing class symmetrical relations and placement class symmetrical and transitive relations (BA, ED, FD, GD, EF/FE, FG/GF, and GE/EG). No word beat patterns were trained.

No Placement Names (S13-S15). Results of equivalence testing and training for these subjects are shown in Figure 6. Subjects acquired both timing and placement class symmetrical and transitive relations (BA, CA, BC/CB, ED, FD, EF/FE). The transitive relations EF/FE (keys/ fingers) did not emerge for S13. After re-training the prerequisite DE and DF (staff placements with keys and fingers), EF/FE emerged. S13 and S15 in pre-testing showed no accurate responding for any relations. S14 showed 70% accuracy on the pre-test for the AB (auditory/symbol beat patterns) relations. No placement letters were

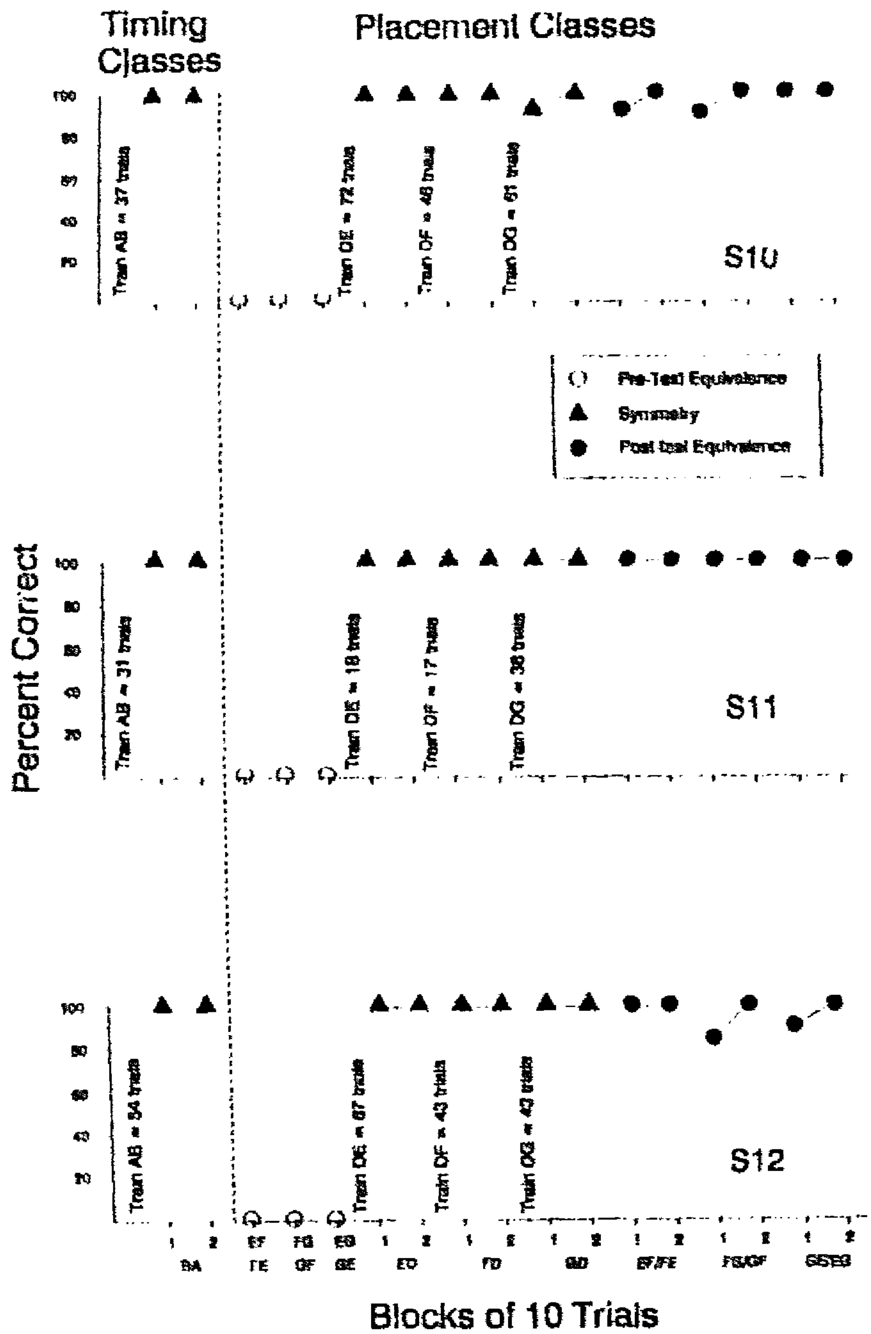
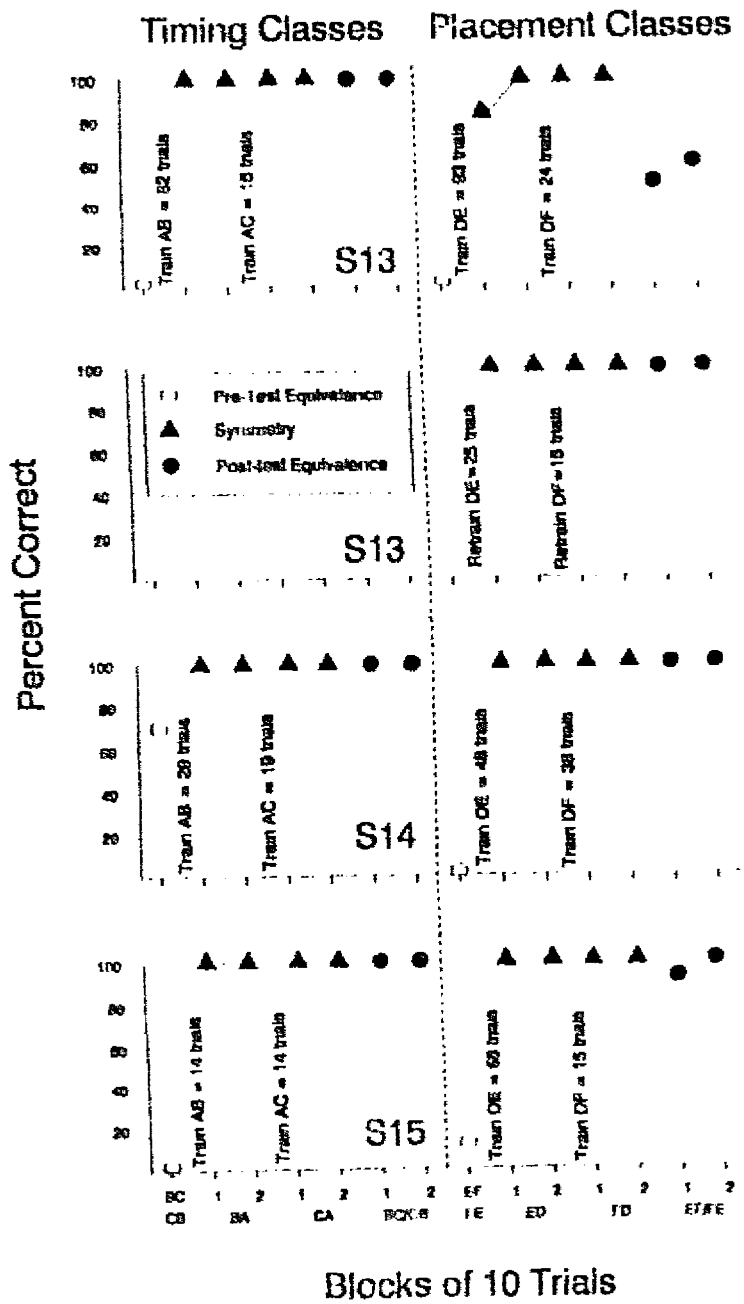



Figure 5. Individual training/testing data for Subjects 10 to 12 of the No Timing Names group. Test data presented as percentages of trials correct (vertical axis) across blocks of 10 trials (horizontal axis). Numbers of training trials are presented in vertical text.




<u>Figure 6.</u> Individual training/testing data for Subjects 13 to 15 of the No Placement Names group. Test data presented as percentages of trials correct (vertical axis) across blocks of 10 trials (horizontal axis). Numbers of training trials are presented in vertical text.

trained.

No Names (S16-S18). Results of equivalence training and testing for *No Name* subjects are presented in Figure 7. Subjects acquired timing class symmetrical equivalence relations and placement symmetrical and transitive equivalence relations (BA, ED, FD, EF/FE). The accuracy for the transitive EF/FE relations for S18 declined to 80% for the second block of 10 trials. No word beat patterns or placement letters were trained.

Keyboard Playing

Pre-tests. None of the No Timing Names, No Placement Names, or No Names subjects showed correct beat, key, or finger selections in pre-tests of keyboard playing.

Post-tests. All subjects were able to perform the pitch sequences after equivalence training and testing. Trials to criterion for correct keyboard playing decreases across pitch sequences for all subjects, as shown in Figure 8. For the No Timing Names group S6 requires 8 trials on the first pitch sequence, decreasing to 2 by the final sequence; S7 begins with 4 trials, ends with 1; and S8 begins with 6 and ends with 2. For the No Placement Names group, S9 begins with 12, decreasing to 5; S10 begins with 6 decreasing to 4; and S11 begins with 4 ends with 3. For the No Names group S12 begins with 17 ends with 3; S13 begins with 19, ends with 5; and S18 begins with 7, ends with 4.

Objective 4: To Compare Whether Keyboard Playing is any More or Less Available than Describing Playing

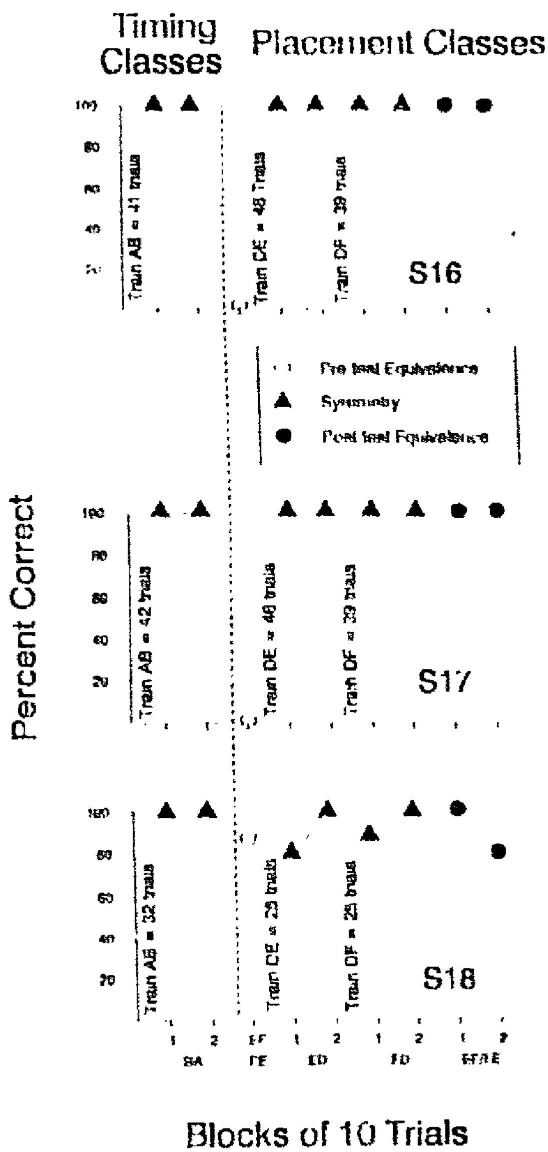



Figure 7. Individual training/testing data for Subjects 16 to 18 of the No Names group. Test data presented as percentages of trials correct (vertical axis) across blocks of 10 trials (horizontal axis). Numbers of training trials are presented in vertical text.

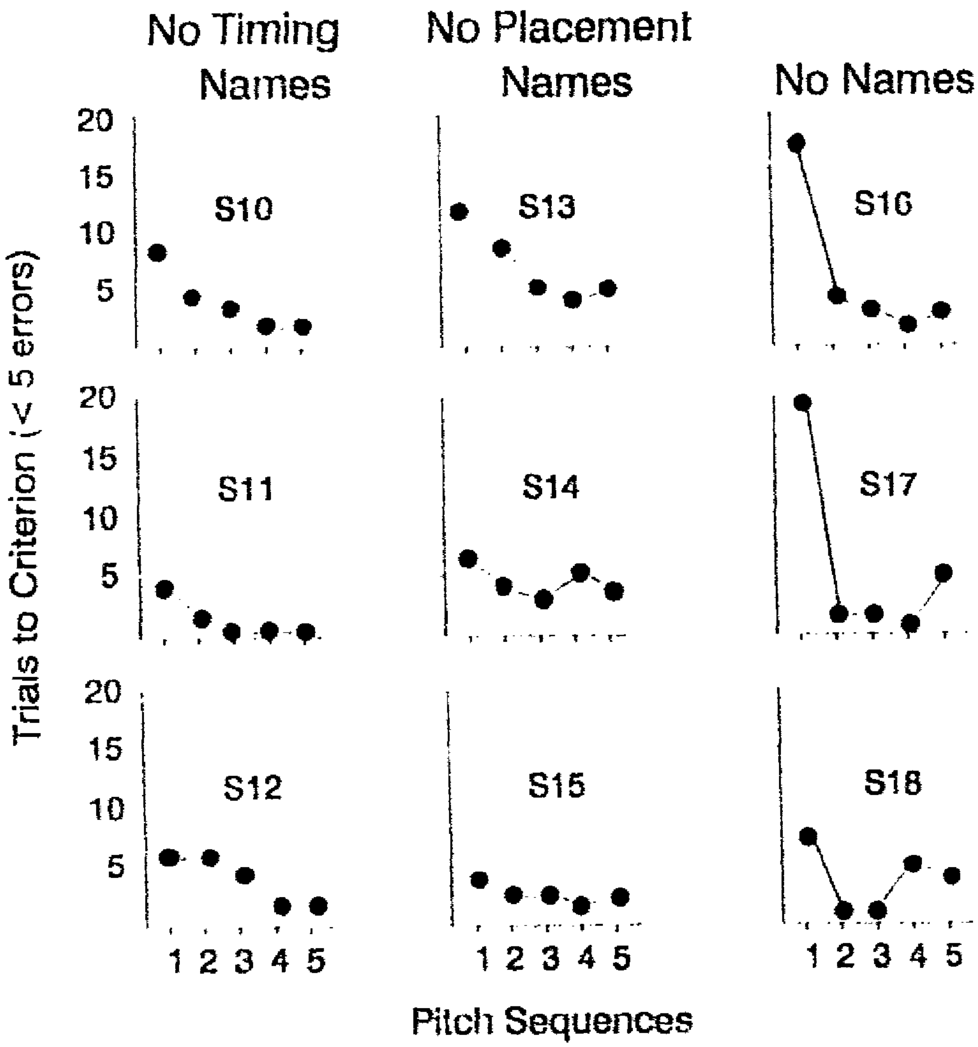
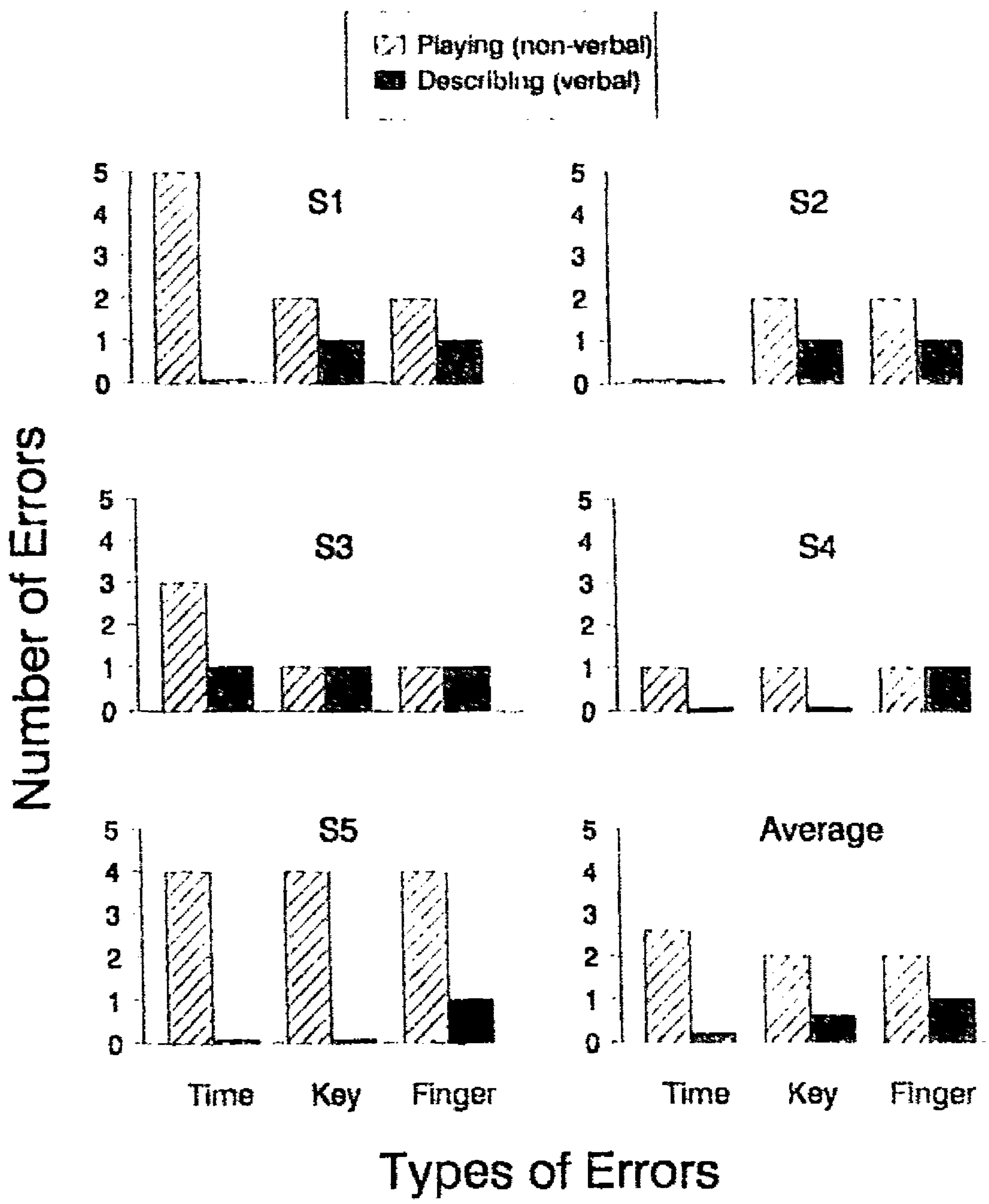



Figure 8. Trials to criterion (less than 5 errors) for each pitch sequence in the keyboard playing test for Subjects 10 to 18 in the No Timing Names, No Placement Names, and No Names group.




<u>Figure 9.</u> Average number of verbal and non-verbal timing, key, and finger errors across all pitch sequence for Subjects 1 to 5 of the Timing and Placement Training group.

<u>Describing Keyboard Playing</u>. Figure 9 compares three types of verbal (describing keyboard playing) and nonverbal (keyboard playing) errors: beat errors, and key and finger selection errors. Generally, subjects showed more errors in keyboard playing than in describing keyboard playing. However, S3 had the same number of errors (verbal as compared to nonverbal) for key and finger keyboard playing and describing playing; S2 had the same number for beat errors; S4 had the same number for finger errors. No subject showed more errors of any type in describing keyboard playing than keyboard playing.

## Discussion

### <u>Objective 1: The Nonverbal Action Based upon Equivalence Classes</u>

A significant contribution of present research is application of equivalence classes to an operant, nonverbal, non-uniform behavior performances. The novel compound stimuli allowed the novel performances to occur. Each compound stimuli contained information from both equivalence classes. However, some training relations were not expressed in the compound stimuli or were altered. Specifically, in the timing paradigm, AB and AC (identifying auditory beat patterns with symbols and words) training required pointing to correct beat patterns; in testing, subjects played specific beat patterns. In the placement paradigm, training stimuli, class D (staff positions), were marked by an X. In testing keyboard playing with compound stimuli, staff positions were marked with stimulus class B (visual note symbols). The names (stimulus class C, word beat patterns; and stimulus class G, letters) were likewise not present in the compound stimulus.

The Nature of Responses as a Function of Trained and Derived Equivalence Relations. Keyboard performance was simultaneous implementation of BA (visual beat patterns with auditory beat patterns), DE (staff placement with keys), DF (staff placement with fingers), and EF (keys with fingers) relations. Simply put, subjects interpreted two classes to form one large stimulus equivalence class, namely the stimulus equivalence class comprising BADEF stimuli (visual beat patterns with auditory beat patterns with staff placements with keys and fingers). Keyboard playing was novel since responses required various random implementation combinations of these relations. Relations had to be implemented simultaneously, but will be discussed individually for clarity.

BA responding (visual beat patterns *to the production of* auditory beat patterns) was never trained or tested. Responding occurred since AB training occurred. BA responding can occur due to symmetry, AB/BA and the changing of the testing context requiring a change in response topography. DE (staff placements to key pressing) and DF (staff placements with fingers) required the same responding as in training. Stimulus class D, however, was altered. Although the *places* on the musical staff were the same as in training, the *symbol* occupying those places were different. These symbols were stimulus class B (visual beat patterns).

The Novel Playing Performances

Subjects were asked "play this pitch sequence as best you can, reading from left to right". Subjects interpreted this to mean playing the keyboard. While subjects had limited musical history, they surely would have seen keyboards being played in the past. Also, the keyboard was directly in front of them. This may be why the subjects did not engage in the many other possible behaviors to the instruction "play this as best you can, reading from left to right".

Keyboard playing required simultaneous implementation of relations from two different classes, and contingency-shaping of the instrument. Such performances are limited to the extent that the behavior requires shaping. All subjects were able to play the pitch sequences. There were however, some unanticipated contingency-related problems.

Difficultly Using the Thumb. Firstly, on practice trials several subjects, S4, S5, S10, S13 and S15 did not use correct the thumb for the "F" key (specifically, the E1F1/F1E1 relations). However, all the other relations were applied correctly. To attain correct E1F1/F1E1 relations the experimenter had to prompt the subjects, as "Remember everything that you learned". No specific prompts were given. Informal post-interviewing revealed that subjects found it difficult to play the keyboard using the thumb.

In any activity that involves shaping, the current repertoire must compete with a history of responding. These subjects found using the thumb cumbersome, perhaps indicating that the behavioral history did not include uses of the thumb in such a dexterous manner.

Problems Masked in the Data Analysis. Secondly, some problems with the contingency-shaping component are masked when the performance of the pitch sequences are analyzed simply as relations. These are somewhat subjective problems of musicality. For example, both S5 and S11 required very few practice trials of the playing performances (M = 2.2 and 1.8 trials to performance criterion, respectively). However, only S11's performances on the keyboard were very smooth. S5's performances by comparison were less smooth, and jerky.

Hand Position. Third, hand position was a factor in the overall smoothness of the performances of the pitch sequences. Especially poor hand position was noted for S3; good hand positions were noted for S11, S14 and S15. Good hand position is an erect wrist with the fingers slightly curled, ready to play any of the given notes. Poor hand position is limp wrist with the fingers either very curled or very straight.

The method of data analysis did not reflect the overall playing performance, rather it reflected the performance of individual notes. The analysis only reveals information about specific relations. Regarding a specific note, it is no more difficult to play an "F" or a "G". However, depending upon where the previous note was and how long it was held influences the subsequent notes. Typically, songs with notes that are close together are easier to play than those with notes that are far apart, and songs with notes held for a long time are easier to play than those with notes held for very short durations.

Over-held Notes. Fourth, S10, S12, S13, and S14 had timing problems. Specifically, they would play one key, then play another key while still holding the first. Self-correction occurred, possibly through the culturally unpleasant sound or the fact that they had to play the same key again. Culturally for the untrained music listener, it is displeasing to hear a cluster of pitches so close together for long durations simultaneously. Subjects may have recognized this and began to respond correctly. This represents an acquisition effect. Perhaps the feedback of the sound shaped the responses. S10 and S13 did ask the experimenter if holding keys constituted errors. The experimenter did not reply.

These problems may be accounted for when examining the subjects' behavioral learning history with respect to playing. In placement training, subjects saw one staff position and played one key that was its associational counter-part. In performance of pitch sequences, the subjects were confronted with all of the learned stimuli simultaneously and may have been trying to perform in such a way as to include all the stimuli simultaneously, instead of sequentially.

Objective 2: The Merging of Stimulus Classes via Compound Stimuli

Subjects were responding to the *merging* of BDE (visual beat patterns/staff placements/keys), and BDF (visual beat patterns/staff placements/fingers) relations. Further, accurate keyboard playing depended upon this and implementation of correct timing (BA relations). BA is symmetrical (AB); correct tone length (beats) was possible with the presentation of the symbols (class B) requiring production of specific tone duration (class A). Subjects were presented with BD (visual beat patterns/visual staff placements) compound stimuli and responded the AEF (auditory beat patterns/keys/fingers) relations. In short, BD allowed subjects to merge responses; to play a specific key with a specific finger for a specific time.

Objective 3: Naming Equivalence Class Members and Its Effect upon Nonverbal Performance Based upon Those Equivalence Classes

Studies that have investigated the role of naming stimuli in the formation of equivalence classes. (Lazar et al., 1984; Sidman et al., 1985; Sidman et al., 1974; Sidman & Cresson, 1973; and Sidman & Tailby, 1982) provide strong evidence that naming is neither necessary nor sufficient for the formation of equivalences. The No Pitch Names subjects did not receive training with letter staff placements. The No Timing Names subjects did not receive training with word beat patterns. No Name subjects received neither training. All subjects were able to play the keyboard, despite this.

Whether given names facilitated keyboard performance is unclear. On average the No Placement Names and No Names groups required more practice trials than did the No Timing Names and the Timing and Placement Training subjects. The No Timing Names subjects reached the criterion for performing pitch sequences in the fewest trails $X=3.1$. No Placement Names subjects and No Names subjects achieved criterion in $X=4.8$ and $X=6.9$ trials, respectively.

This may suggest that only placement, and not timing names facilitated keyboard performance. This makes sense. Placement names were labelling absolute stimuli, keys and fingers. Timing names were labelling stimuli in relation, for example, this symbol means this pitch is twice as long in duration as the previous. As well, musiciar name keys with letters, not with beat sequences. Alternatively, these findings may be related to the outcomes on the Bentley Test of Musical Ability. Mean scores for the Bentley Test were 74.3%, 73.0% and 64.3% for the No Timing Names, No Placement Names, and No Names subjects groups, respectively. According to the results of the Bentley Test, the No Names subjects had a lower musical ability profile. This may account for the larger number of trials to criterion by the No Names subjects for playing the keyboard. Intra-group variability is high with respect to trials to criterion, and the Bentley scores. Also, subject groups were small (N=3 per group) so differences in trials to criterion for playing keyboard responses could reflect individual and not experimental differences. It is also quite possible that subjects supplied their own names. The experimenter did not ask the subjects if they supplied their own names.

Experiment names may have been competing with past histories of naming. Specifically, letter names for fingers ("F, G, A, B") may have been competing with the names: "thumb, index, middle and ring finger", respectively. These two name sets may or may not have been placed in relation. The experimenter did not ask if subjects provided names for their fingers or not.

<u>Objective 4: To Determine Whether Keyboard Playing is any More or Less Available than Describing Playing</u>

Testing for describing playing involved slightly different responses than in training, and demonstrated the process of abstraction. Verbal testing required changes in the response topography; and existing symmetrical relations in the subjects' repertoire. Testing of keyboard playing required simultaneous responding to relations in both timing and placement equivalence classes. Testing of description of playing required responding to individual relations. Since the compound stimuli present relations simultaneously, specific relations were abstracted.

To reiterate, these questions were asked:

a) What is the letter name of the staff placement? (DG relations)

b) With which finger is appropriate to play the staff placement (DF relations)

c) Which key is appropriate to play this staff placement? (DE relations)

d) How many beats does the note receive? (BA relations)

e) Is the note a quarter-beat, half-beat or a whole-beat? (BC relations)

Verbal testing for DG (staff placements/letter names) DF (staff placements/fingers), and DE (staff placements/keys) relations required subjects to label comparison stimuli, not point to comparisons or press keys as in training. Labelling involved: placing an "X" on printed letter (DG), on a key of a picture of a keyboard (DE), and on a picture of a right hand (DF). These responses were not unprobable, since pictorial representations closely resembled a keyboard and a hand.

Verbal testing for BC/CB (visual/word beat patterns), also required changes in response topography: from pointing to a word in the presence of a symbol (CB) to circling a word in the presence of a symbol. Similarly, verbal testing for BA (visual/auditory beat patterns) changed response topography from pointing to circling, and depended upon existing symmetrical relations. In verbal testing the auditory beat patterns were substituted by the number of beats (1, 2, or 4) *each note* receives. This substitution is actually symmetrical responding of auditory beats with numbers (1, 2, and 4). These symmetrical relations almost surely were in the subjects' repertoire. Accurate keyboard playing depended upon these relational discriminations (i.e. a whole-beat is 4 times the duration of a quarter-beat, therefore whole-beat equals 4).

The compound musical stimuli used in testing describing keyboard playing and in testing keyboard playing may be conceptualized as an instruction or a rule. Playing keyboard performances showed improvement across compound stimuli in the absence of explicit feedback. Almost all subjects exhibited a sharp decrease in number of trials to criterion between the first and second pitch sequences for keyboard playing. The verbal description data show that the subjects were able to describe the musical instructions quite well. Perhaps subjects could discriminate between correct and incorrect keyboard playing performances well before they could actually execute accurate keyboard playing performances. Simply, subjects knew what to do, but had to practice doing it. As more pitch sequences are played, more practice occurs (contingency shaping). This accounts for the general negative slope of all the graphs depicting the practice trials to criterion.

All subjects involved in training with either or both Timing Names and Placement Names were able to form equivalence classes with these names. It is reasonable to suggest these language-able subjects read the timing and placement names as well as pointed to them in training. Thus, describing playing which was articulating the DG (staff placements/letter names), DF (staff placements/fingers), DE (staff placements/keys), BA (visual/auditory beat patterns), and BC (visual/word beat patterns) relations, emerged more readily than keyboard playing. The comparison between describing keyboard playing and keyboard playing was not absolute.

Limitations of the Investigation

The compound stimuli permitted the subjects to perform a complex behavior, not currently in their repertoire. The common stimuli from the timing and placement paradigms were not directly paired, as in other studies (Lazar et al., 1984; Sidman et al., 1985; and Wetherby et al., 1983). The training gave the subjects two instructions or rules: which note to play, and for how long. Theoretically, this may suggest that we can, sometimes at least, follow two rules simultaneously, if it is possible to do so.

Most research in this area has used persons with developmental delays, since it may be considered useful for these subjects to get maximin learning from minimum training. (Gast, VanBiervliet, & Spradlin, 1979; Hollis, Fulton, & Larson 1986; Mackay & Sidman, 1984; Mackay, 1985; Mackay & Ratti, 1990; McConagh, McIlvane & Stoddard, 1984; Sidman & Kirk, 1986; Spradlin & Saunders, 1986; VanBiervliet, 1977). However, persons with developmental delays often display *stimulus overselectivity*. Stimulus overselectivity "occurs when an individual faced with a complex [or compound] stimulus responds to only one or to a reduced number of relevant components [of the stimulus]" (Bailey, 1981, p. 239). Bailey (1981) discovered that stimulus overselectivity occurs in learning disabled, mentally handicapped, and to some extent, even young normal children. Bailey concludes "as mental age increases, overselectivity decreases...however, this relationship may be weak, especially across differing disabilities" (Bailey, 1981, p.245). Overselectivity is especially common in autistic people (Koegel & Wilhelm, 1973; Lovaas & Schreibman, 1971; Lovaas, Koegel, & Schreibman, 1979; and Reynolds, Newson & Lovaas, 1976). Recent evidence (Socraci, Deckner, Baumeister & Carlin, 1990) suggests that stimulus overselectivity may be minimized by "salience-enhancement procedures", that is making the relevant aspects of stimuli larger, louder, etc. than the irrelevant aspects (Socraci et al., 1990, p. 305). However, there were no such procedures in this study. Normal adult humans were able to respond to the compound stimuli in this study, but it is doubtful that autistic, learning disabled, or mentally handicapped individuals would be able to respond in such a manner.

Further Research Directions

Perhaps more complex skills could be taught to autistic, learning disabled, and mentally handicapped individuals if the salience-enhancement procedures were used in such stimulus equivalence designs. Practically speaking, the normal adults used in this study could have probably learned how to play the simple pitch sequences through traditional verbal explanations, not the MTS procedure. Skills that encompass such complex discriminations are not easy for developmentally delayed populations. Careful structuring as in this approach with salience-enhancement procedures may point to further directions to teach complex skills to such populations.

Devany et al. (1986) discovered that transitive relations will emerge in language-abled children and not with language-disabled children. Equivalence designs may have diagnostic potential. What is missing from current research, and this study, is why some individuals can perform transitive associations and some cannot.

Functional equivalence. As Green et al. (1990) suggest, a more useful direction for stimulus equivalence may be with functional equivalences. Functional equivalences describe how different stimuli produce the same action (i.e., a stop sign, a red traffic light, and a raised policeman's hand may all occasion one to step on the brakes or cease walking). This requires a more critical examination of discriminative stimuli. Functional equivalence is critical since how we operate with respect to stimuli should be the focus of research in this area. When using arbitrary stimuli, the research focus is whether equivalences can occur and under which conditions (Lazar, 1977; Lazar et al., 1984; Sidman et al., 1982; Sidman et al., 1985; Sidman & Tailby, 1982; Spradlin et al., 1973; Stromer & Osborne, 1982; Touchette,1971; Whetherby et al., 1983; and Wulfert and Hayes, 1988).

Reading and communicative applications of the stimulus equivalence paradigm. Sidman & Osborne (1973) describe a stimulus equivalence procedure in which two handicapped children were able to discriminate visual pictures with words (i.e., ear, cow, man, car, axe, cat, etc.) at the end of training. While this is useful, in the context of a communicative program; its use may be limited. As reported by speech pathologist and founder of the Hanen Project, Manolson (1984), communication is most enhanced when words are taught in the natural environment. These words may generalize better across environments, and there is more consideration to which words are chosen and the motivational state of the learner.

## Conclusions

Conceptually, acquisition of relations through training/testing in timing and placement paradigms provided rules or instructions to effect keyboard performances. Keyboard playing may be conceptualized as rule following. The No Timing Training and No Placement Training subjects were given incomplete rules, and therefore unable to follow them.

Verbal instruction is verbal behavior. Verbal behavior is largely symmetrical interaction. The results of the current study suggest that symmetrical responding need not be explicitly trained. Stimuli may be associated through symmetry or transitivity. More importantly, stimuli may become associated as a function of context. Contexts continually change. As contextual changes occur, past symmetrical discriminations may merge with current circumstances.

As a technology, stimulus equivalence designs may be useful in examining what stimuli are associated for any behavior. This may be an important investigative role.

What is missing from current equivalence investigations is communicative function. Symmetrical responding may explain how labelling occurs. What it does not explain is what is the communicative function(s) with the use of labels. This is significant. Without such investigation, it may be unclear as to what stimuli actually are associated.

**References**

Bailey, S.L. (1981). Stimulus overselectivity in learning disabled children. *Journal of Applied Behavior Analysis*, *14*, 239-248.

Bentley, A. (1966). *Musical Ability and Its Measurement*. London, England: George G. Harrap.

Cuddy, L.L. (1971). Absolute judgement of musically related pure tones. *Canadian Journal of Psychology*, *25*, 42-55.

Cuddy, L. L., Cohen, A. J., & Dewar, K. M. (1978, June). *Judgement of musical intervals: Relations between patterns of accuracy and musical training*. Paper presented at the 39th annual meeting of the Canadian Psychological Association, Ottawa, Canada.

Cuddy, L. L., Cohen, A. J., & Mewhort, D. J. K. (1981). Perception of structure in short melodic sequences. *Journal of Experimental Psychology: Human Perception and Performance*, *7*, 869-883.

Cuddy, L.L., Cohen, A.J., & Miller, J. (1979). Melody recognition: The experimental application of rules. *Canadian Journal of Psychology*, *33*, 148-157.

Devany, J. M., Hayes, S. C., & Nelson, R. O. (1986). Equivalence class formation in language-able and language-disabled children. *Journal of the Experimental Analysis of Behavior*, *46*, 243-257.

Dewar, K. M., Cuddy, L. L., & Mewhort, D. J. K. (1977). Recognition memory for single tones with and without context. *Journal of Experimental Psychology, 8*, 60-67.

Dixon, M. D. & Dixon, L. S. (1978). The nature of standard control in children's matching-to-sample. *Journal of the Experimental Analysis of Behavior, 30*, 205-212.

Feldstein, S. (1985). *Alfred's Pocket Dictionary of Music*. Sherman Oaks, California: Alfred Publishing Co.

Fields, L. Verhave, T., & Fath, S. (1984). Stimulus equivalence and transitive associations: A methodological analysis. *Journal of the Experimental Analysis of Behavior, 42*, 143-157.

Gast, D. L. , VanBiervliet, A., & Spradlin, J. E. (1979). Teaching number-word equivalences: A study of transfer. *American Journal of Mental Deficiency, 83*, 524-527.

Green, G., Mackay, H. A., McIlvane, W., Saunders, R. R., & Socraci, S. A. (1990). Perspectives on relational learning in mental retardation. *American Journal on Mental Retardation, 95*, 249-259.

Guess, D. & Baer, D. M. (1973) An analysis of individual differences between receptive and production language in retarded children. *Journal of Applied Behavior Analysis, 6*, 311-329.

Hayes, S., Brownstein, A. J., Haas, J. R., & Greenway, D. (1986). Instructions, multiple-schedules and extinction: Distinguishing rule-governed from schedule controlled behavior. *Journal of the Experimental Analysis of Behavior, 46*, 137-148.

Hollis, J. H., Fulton, R. T., & Larson, A. D. (1986). An equivalence model for vocabulary acquisition in profoundly hearing impaired children. *Analysis and Intervention in Developmental Disabilities, 6*, 331-348.

Innocenti, Mark S., Fichtl, Barbara J., & Rule, Sarah (1987, May). *A comparison of stimulus equivalence training procedures in the establishment of classes of numerical stimuli.* Paper presented at the annual meeting of the Association for Behavior Analysis, Nashville, TN.

Koegel, R.L. & Schreibman, L. (1973). Selective responding to the components of multi visual cues by autistic children. *Journal of Experimental Child Psychology, 15*, 442-453.

Krumhansl, C.L. (1983). Perceptual structures for tonal music. Music Perception, 1, 28-62.

Lazar, R. (1977). Extending sequence-class membership with matching-to-sample. *Journal of the Experimental Analysis of Behavior, 27*, 381-392.

Lovaas, O.I. & Schreibman, L. (1971) Stimulus overselectivity of autistic children in a two stimulus situation. *Behavior Research and Therapy*, 9, 305-310.

Lovaas, O.I., Koegel, R.L., & Schreibman, L. (1979). Stimulus overselectivity in autism: A review of research. *Psychological Bulletin*, *86*, 1236-1254.

Mackay, H. (1985). Stimulus equivalence in rudimentary reading and spelling. *Analysis and Intervention in Developmental Disabilities*, *5*, 373-387.

Makay, H., & Ratti, C. (1990) Position numeral equivalences and delayed position recognition span. *American Journal on Mental Retardation*, *95*, 271-282.

Mackay, H., & Sidman, M. (1984). Teaching new behavior via equivalence relations. In P. H. Brooks, R. Sperber, & C. McCauley (Eds.), *Learning and Cognition in the Mentally Retarded* (pp. 493-513). Hillside, NJ: Erlbaum.

Manolson, A. (1984). *It takes two to talk: A Hanen early language parent guide book*. Toronto: Hanen Early Language Resource Center.

Reynolds, B.S., Newson, C.D., & Lovaas, O.I. (1974). Auditory overselectivity in autistic children. *Journal of Abnormal Child Psychology*, *2*, 253-263.

Saunders, R. R., Saunders, K. J. & Spradlin, J. E. (1990). Long-term stability of stimulus relations in the absence of training or practice. *American Journal on Mental Retardation*, *95*, 297-303.

Saunders, R. R., Watcher, J. A. & Spradlin, J. E. (1988). Establishing auditory stimulus control over an eight-member equivalence class via conditional discrimination procedures. *Journal of the Experimental Analysis of Behavior*, *49*, 95-115.

Sidman, M. (1971). Reading and auditory-visual equivalences. *Journal of Speech and Hearing Research*, 14, 5-13.

Sidman, M., Kirk, B., & Willson-Morris, (1985). Six member stimulus class generated by conditional procedures. *Journal of the Experimental Analysis of Behavior*, *43*, 21-42.

Sidman, M., & Osborne, C. (1973). Reading and cross-modal transfer of stimulus equivalences in severe retardation. *American Journal of Mental Deficiency*, *5*, 515- 523.

Sidman, M., Osborne, C. & Willson-Morris, M. (1974). Acquisition of matching-to-sample via mediated transfer. *Journal of the Experimental Analysis of Behavior*, *22*, 261 273.

Sidman, M., Rauzin, Lazar, R., Cunningham, S., Tailby, & Carrigan, P. (1982). A search for symmetry in the conditional discriminations of rhesus monkeys, baboons, and children. *Journal of the Experimental Analysis of Behavior*, 37, 23-44.

Sidman, M. & Tailby, W. (1982). Conditional discriminations vs. matching-to-sample: An expansion of the testing paradigm. *Journal of the Experimental Analysis of Behavior, 37,* 5-22.

Sidman, M., Willson-Morris, M., & Kirk, B. (1986). Matching-to-sample procedures and the development of equivalence relations: The role of naming. *Analysis and Intervention in Development Disabilities, 6,* 1-19.

Skinner, B.F. (1957). *Verbal behavior.* Englewwod Cliffs, N.J. : Prentice-Hall.

Skinner, B.F. (1978). *Reflections on Behaviorism and Society.* Englewwod Cliffs, N.J.: Prentice-Hall.

Spradlin, J. E., Cotter, V. W., & Baxley, N. (1973). Establishing a conditional discrimination withou direct training: A study of transfer with retarded adolescents. *American Journal of Mental Deficiency, 77,* 556-566.

Spradlin, J. E., & Saunders, R. R. (1986). The development of stimulus classes using matching-to-sample procedures: Sample classification versus comparison classification. *Analysis and Intervention in Developmental Disabilities,* 6, 41-58.

Socraci, S.A., Deckner, C.W., Baumeister, A.A., & Carlin, M.T. (1990). Attentional functioning and relational learning. *American Journal on Mental Retardation, 95,* 304-315.

Stromer, R., & Osborne, J. G. (1982). Control of adolescents' arbitrary matching-to-sample by positive and negative stimulus relations. *Journal of the Experimental Analysis of Behavior, 37,* 329-348.

Touchette, P. E. (1971). Transfer of stimulus control: Measuring the moment of transfer. *Journal of the Experimental Analysis of Behavior, 15,* 347-354.

VanBierliet, A. (1977). Establishing words and objects as functionally equivalent through manual sign training. *American Journal of Mental Deficiency, 82,* 178-186.

Wulfert, E., & Hayes, S.C. (1988). The transfer of a conditional ordering response through conditional equivalence classes. *Journal of the Experimental Analysis of Behavior, 50,* 125-144.

Wetherby, B., Karlan, G. R. & Spradlin, J. E. (1983). The development of derived stimulus relations through training in arbitrary matching sequences. *Journal of the Experimental Analysis of Behavior, 40,* 69-78.

## Appendix A

The informed consent application used.

I understand that I am participating in a psychological research experiment under the principle investigator of Scott Thompson. I realize that my participation is voluntary and that all results will be kept confidential. I am aware that my participation requires approximately three hour long sessions. Finally, I understand that if I have any questions that I may ask Dr. Konopasky, the chairperson of the psychology department.

____________________________

Signature of Participant

____________________________

Signature of Witness

____________________________

Date

## Appendix B

An explanation of the Bentley Test of Musical Ability.

The Bentley Test of Musical Ability was devised in 1966. The test has four sub-tests: pitch discrimination, tonal memory, rhythmic memory and chord analysis. In the pitch discrimination sub-test subjects are presented with two tones (a sound pair) consecutively and asked to indicate if the second sound is the same as the first, or whether it moves up or down. All sound pairs used A=440 cycles per second (c.p.s.) as the reference tone. The differences in pitch between the sound pairs is small (i.e. less than or equal to 26 c.p.s. or stated another way a semi-tone or less). In the tonal memory sub-test subjects are presented with two 5-note tunes presented consecutively. Subjects indicate whether the second tune was the same or different from the first tune. None of the second tunes is in fact the same as the first, but subjects who do not recognize a difference should have the opportunity of stating this. One note in the second tune was altered. The alterations were sometimes whole-tones, and sometimes semi-tones. If different, subjects stated the sequence position of the altered note. The positions of the changed notes were random between the first and the fifth notes. The rhythmic memory sub-test consists of paired comparisons, each being a 4-pulse (beat) rhythmic figure. Subjects are asked to indicate whether the two rhythmic figures (auditory beat sequences) presented consecutively are the same or different. If different, subjects are asked to indicate on which beat the change is made. There was no change in pitch between the rhythmic figures. Positions of the changed beat occur equally but randomly between the first,second, third and fourth beats. The chord analysis sub-tests consist of two, three and four-note chords. A chord is two or more pitches heard simultaneously. Subjects are asked to indicate how many pitches or notes comprise a chord. No adjacent chords have any note in common.

Validity

Three groups of highly skilled musicians took the test: 120 graduates in music (university degrees), 22 professional string teachers, and 18 choral scholars. The music graduates scored 92%, the string teachers 87%, and the choral scholars 81%. As well, 47 music teachers rated their students on a four-point scale: A = musical, B = fairly musical, C = not very musical , and D = unmusical. Then the Bentley Test was administered to 314 of the music teachers' students. A comparison of the test results with the rating scales occurred. The chi-squared null-hypothesis was disproved at the 1% significance level. Another test of validity compared school music examination scores in a American grammar school with the Bentley test. Correlation was 0.94, on a sample of 77 boys, mean age 11 years 1 month. Both test scores were near-normal distribution. For further explanation see Bentley, 1966.

Reliability

The Bentley Test was administered to 90 girls and 90 boys and then re administered four months later. Scores for each trial were normally distributed, the correlation between administrations was 0.84.