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**GENERALIZED EQUIVALENCE CLASSES AS RESPONSE TRANSFER
NETWORKS**

**by
James Belanich**

**A dissertation submitted to the Graduate Faculty in Psychology in partial
fulfillment of the requirements for the degree of Doctor of Philosophy,
The City University of New York**

2001

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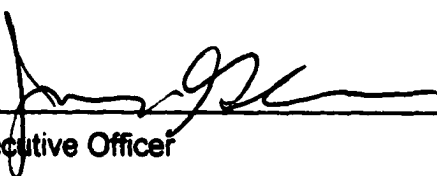
Approval Page

This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

9/4/01
Date


Chair of Examining Committee

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Abstract**GENERALIZED EQUIVALENCE CLASSES AS RESPONSE TRANSFER
NETWORKS**

by

James Belanich**Advisor: Professor Lanny Fields**

College students formed two perceptual classes and then two 3-node 5-member equivalence classes in a matching-to-sample procedure. One stimulus in each perceptual class was also a member of one equivalence class. The subjects in Groups 1 and 2 formed equivalence classes with nodes that served two stimulus functions. The subjects in Group 3 formed equivalence classes with nodes that served one stimulus function. Although the number of functions served by the nodal stimuli did not affect the likelihood of equivalence class formation, it had a direct effect on the speed of learning the conditional discriminations that were the prerequisites of equivalence class formation. All subjects in all groups then demonstrated generalized equivalence classes by selecting members of the equivalence class in the presence of all members of the linked perceptual class. Then, different responses were trained to one stimulus in each class and to a stimulus that was not a member of either class. The responses were trained to different class members in different groups. All subjects in Groups 1 and 2 and half of the subjects in Group 3 showed transfer of the response to all remaining class members, regardless of the class member to

which the response was trained. The remaining subjects in Group 3 did not show response transfer. Thus, the likelihood of response transfer through a generalized equivalence class varied with the number of functions served by the nodal stimuli in a class. For the subjects who failed the response transfer test, only a portion of the perceptual classes became related to the members of their linked equivalence classes. Thus, the failure of response transfer was preceded by a limited linkage of stimuli in perceptual and equivalence classes. These results suggest that the strength of relations among the stimuli in an equivalence class was influenced by the number of functions served by nodal stimuli in the class.

Acknowledgments

I would like to thank Dr. Lanny Fields for all of his help throughout my entire time at the City University of New York. I have learned a lot, and I truly appreciate all of your time and effort. I would also like to thank Dr. Poulson, Dr. Hemmes, Dr. Balsam, and Dr. Allan for your insightful comments on my dissertation. Additionally, I would like to thank all of the members of the Learning Lab at Queens College over the years that I have been there, especially Tony, Ken, Priya, and Devorah. Your made coming to work fun.

Most importantly, I would like to thank my wife Mary for putting up with me throughout this endeavor. I could not have done it without your love and support.

Table of Contents

Approval Page	ii
Abstract	iii
Acknowledgments	v
Introduction	1
Equivalence classes.	1
Structure of equivalence classes.	3
Response transfer across equivalence classes.	5
Generalized equivalence classes	7
Response transfer across generalized equivalence classes	9
Extending the analysis of response transfer	13
Research Goals	14
Method	15
Subjects	15
Apparatus	15
Hardware	16
Stimuli	16
Procedure	16
Phase 1: preliminary training	16
Phase 2: perceptual class formation	19
Phase 3: equivalence class formation	20
Phase 4: Emergence of generalized equivalence classes	22
Phase 5: discrimination training	22
Phase 6: response transfer test	24
Phase 7: assessment of discriminability	24
Results and Discussion	26
Perceptual classes from primary generalization tests	26
Perceptual class width	28
.....	28
Equivalence class formation	28
Generalized equivalence classes	29
Prediction of generalized equivalence class width from perceptual class width	32
Discrimination training	34
Response transfer in generalized equivalence classes	35
Untrained responses in transfer tests	38
Effects of training stimuli and nodal functions on response transfer ...	38
Predicting generalized functional class width	40
Predicting failure of response transfer	41

Discriminability	42
General Discussion	43
Merger of perceptual and equivalence classes	43
Predictability of class membership	44
Acquisition of conditional and simple discriminations	45
Generality of response transfer	47
Possible determinants of response transfer performances	48
Determinants of response transfer and class shrinkage: an explanatory model	50
Appendix A	53
Appendix B	68
Appendix C	71
References	112

List of Tables

Table 1	77
Table 2	78
Table 3	79

List of Figures

Figure 1	80
Figure 2	82
Figure 3	84
Figure 4	85
Figure 5	87
Figure 6	89
Figure 7	91
Figure 8	92
Figure 9	94
Figure 9	96
Figure 10.	97
Figure 11.	98
Figure 12.	100
Figure 13	102
Figure 14.	104
Figure 15.	106
Figure 16.	108
Figure 17.	110

Generalized Equivalence Classes as Response Transfer Networks

Introduction

Equivalence classes. An equivalence class is a set of perceptually disparate stimuli, all of which have become related to each other (Fields & Verhave, 1987; Sidman & Tailby, 1982). An equivalence class has been formed when $N-1$ stimulus-stimulus relations are trained among N stimuli (N must be greater than or equal to 3) and the remaining (N^2-N-1) untrained relations emerge without direct training (Fields & Verhave, 1987; Sidman, 1980, and Sidman & Tailby, 1982). For example, using four stimuli (A, B, C, and D), AB, BC, and CD relations can be trained using a matching-to-sample conditional discrimination procedure. When training the AB relation, A is the sample and B is the comparison. When training the BC relation, B is the sample and C is the comparison. When training the CD relation, C is the sample and D is the comparison. After training the conditional relations, the remaining untrained relations (BA, CB, DC, AC, BD, CA, DB, AD, and DA) emerge without the benefit of feedback (Fields & Verhave, 1987).

Relations among the stimuli in equivalence classes must have the properties of symmetry and transitivity alone and in combination. In the example mentioned above, symmetry is demonstrated by the emergence of class-consistent performances in the presence of BA, CB, and DC probes. Although the criterion for class-consistent performance has varied across experiments, usually, it has been set at near 100% accuracy. In symmetry probes, the stimuli used are the same as those used in the trained relations, except that the order of

presentation is reversed; the stimulus used as a sample in training becomes a comparison and the stimulus used as a comparison in training becomes a sample. Transitivity is demonstrated by the emergence of class-consistent performances in the presence of the AC, BD, and AD probes. In transitivity probes, the order of presentation remains consistent with the trained relations, but the stimulus pairs were not paired together in training. Instead, the stimuli are linked by training to a common stimulus. This common stimulus trained to at least two other members of the class is called a node (Fields & Verhave, 1987). The number of nodes that link stimuli that are related by transitivity can vary. For example, the AC and the BD relations are considered 1-node transitive relations, and the AD relation is considered a 2-node transitive relation.

It is also necessary to demonstrate that relations among the stimuli have the combined properties of symmetry and transitivity. This type of trial, a combination of symmetry and transitivity trials, is called an equivalence probe. In equivalence probes, the order of presentation is reversed and the stimulus pairs were not paired together in training (Fields & Verhave, 1987; Sidman, 1994). Equivalence is demonstrated by the emergence of class-consistent performances in the CA, DB, and DA probes. The CA and DB relations are considered 1-node equivalence relations and the DA relation is considered a 2-node equivalence relation. To unequivocally demonstrate an equivalence class, all relational properties, symmetry, transitivity, and equivalence must be demonstrated.

Technically, the property of reflexivity must also be demonstrated to conclude that a set of stimuli are equivalent to each other. Reflexivity is

demonstrated by the emergence of class-consistent performances in the presence of AA, BB, CC and DD probes in the current example. In many equivalence class experiments conducted with typically functioning adults, reflexivity tests are not conducted because it is assumed that these individuals have a reflexivity repertoire.

Structure of equivalence classes. The structure of equivalence classes is defined by four parameters: class size, the number of nodes, the distribution of singles, and directionality of training (Fields, Hobbie-Reeve, Adams, & Reeve, 1999; Fields & Verhave, 1987). Recent research has shown that at least three of these structural variables influence a) the likelihood of equivalence class formation, and b) the performances occasioned by stimuli in equivalence classes.

Class size is defined by the number of stimuli in the class. Class size has an inverse relation with the likelihood of equivalence class formation (Arntzen & Holth, 1997; Buffington, Fields, & Adams, 1997; Fields, Hobbie-Reeve, Adams, & Reeve, 1999). This effect has been shown across various training paradigms. In addition, Fields, Reeve, Rosen, Varelas, Adams, Belanich, and Hobbie (1997) showed that class size of preliminary equivalence class has a direct relationship with the probability of the establishment of subsequent equivalence classes.

A node is a stimulus which is paired with at least two other stimuli during training. An equivalence class of N stimuli must have at least 1 node and can have up to N-2 nodes. The remaining stimuli which are not nodes are singles. For example, a 4-member class established after the training of the AB, BC, and CD conditional discriminations would have 2 nodes (the B and C stimuli) and 2

singles (the A and the D stimuli), while a class established after the training of the AB, AC, and AD conditional discriminations would have 1 node (the A stimulus) and 3 singles (the B, C, and D stimuli). A number of studies have shown how nodal distance influences the relations among the stimuli in equivalence classes (Bentall, Dickins, & Fox, 1993; Fields, Adams, Verhave, & Newman, 1990; Fields, Adams, Verhave, & Newman, 1993; Fields, Landon-Jimenez, Buffington, & Adams, 1995; Spencer & Chase, 1996). Likelihood of passing emergent relations is inversely related to the number of nodes separating the sample and comparisons in a particular emergent relation (Fields, Adams, Verhave, & Newman, 1990; Fields, Adams, Verhave, & Newman, 1993; Fields, Landon-Jimenez, Buffington, & Adams, 1995). The time required by subjects to select class consistent comparisons during tests of emergent relations is directly related to nodal distance between the sample and comparisons in a particular emergent relation (Bentall, Dickins, & Fox, 1993; Spencer & Chase, 1996).

The directionality of training is determined by the functions (sample or comparison) served by the stimuli during training. Some studies have shown how the directionality of training, which specifies the function served by each stimulus in the training of the conditional discriminations, influences likelihood of equivalence class formation. During the training of a conditional relation, one stimulus functions as the sample, while the other stimulus functions as a comparison. Different patterns of training directionality result in equivalence classes with different structures. For example, a 3-node 5-member class can be established by training the conditional discriminations AB, BC, CD, and DE, which

would produce a class with a structure represented as A->B->C->D->E. In this structure, all nodal stimuli serve two functions in training. The B, C, and D stimuli serve both as samples and comparisons. Alternatively, training the conditional discriminations AB, CB, CD, and ED would produce a class with a structure represented at A->B<-C->D<-E. In this structure, each nodal stimulus serves only one function in training. In addition, nodes B and D serve as comparisons only, while node C serves as a sample only. A number of recent studies have shown that directionality of training influenced the likelihood of equivalence class formation (Fields, Hobbie-Reeve, Adams, & Reeve, 1999; Hall, Ray, & Bonardi, 1993; Johns & Williams, 1998; Saunders, Wachter & Spradlin, 1988; Smeets, Leader, & Barnes, 1997; Spradlin & Saunders, 1986). Saunders and Green, (1999) determined that among 1-node classes containing 3-members, when during training the node functioned as a comparison only, subjects were more likely to form classes than when the node functioned as a sample only. Fields, Hobbie-Reeve, Adams, and Reeve (1999) demonstrated that this difference between comparison-as-node training versus sample-as-node training interacted with class size. In summary, then, structural parameters of equivalence classes influence the performances occasioned by the stimuli in these classes.

Response transfer across equivalence classes. If stimuli are functioning as members of an equivalence class, the class should also function as a transfer network (Fields & Reeve, 2000; Sidman, 1994). Thus, if a novel response is reinforced in the presence of one member of an equivalence class, that same response is likely to be evoked by the other members of the equivalence class

with no direct training. Response transfer among members of equivalence classes has been demonstrated with a variety of response topographies, such as: a) oral naming (Sidman, 1971; Sidman & Tailby, 1982), b) key pressing (Barnes & Keenan, 1993; Fields, Adams, Buffington, Yang, & Verhave, 1996; Fields, Landon-Jimenez, Buffington, & Adams, 1995; Rehfeldt & Hayes, 1998), c) waving and clapping (Barnes, Browne, Smeets, & Roche (1995), and d) responses trained by Pavlovian conditioning (Dougher, Auguston, Markham, Greenway, & Wulfert, 1994; Roche & Barnes, 1997, Augustson, Dougher, & Markham, 2000; Barnes-Holmes, Keane, Barnes-Holmes, & Smeets, 2000). These demonstrations of response transfer among members of equivalence classes suggest that it is a general phenomenon that is not constrained by response topography. Response transfer among stimuli in an equivalence class is beneficial because it minimizes the training that is required to occasion a particular response in the presence of all members of the equivalence class (Augustson, Dougher, & Markham, 2000; Dougher, 1994; Goldiamond, 1966). If all members of an equivalence class occasion the same response after that particular response is reinforced in the presence of only one member of the equivalence class, the class of stimuli are also acting as a functional class (Goldiamond, 1966; Sidman, 1994).

Only one study, Fields, Landon-Jimenez, Buffington, and Adams (1995) assessed the influence of one of the four parameters of equivalence classes on response transfer, that parameter was nodal distance. In Fields, et al. (1995) two 5-member 3-node equivalence classes were established after training of the AB,

BC, CD, and DE conditional relations. After both equivalence classes were established, incompatible responses were trained to A1, A2, E1, and E2. Responses transferred only to stimuli that were members of the same class; no cross-class response transfer was demonstrated. The probability of response transfer of a particular response in the presence of a particular stimulus was an inverse function of that nodal distance that separated the test stimuli from the stimulus to which the response was trained. Thus, at least one structural variable, nodal distance, influences function transfer among the stimuli in an equivalence class. This suggests that other structural variables might also influence response transfer among the stimuli in equivalence classes.

Generalized equivalence classes. An equivalence class contains a fixed number of stimuli that become functionally substitutable for one another. Stimuli that resemble one member of an equivalence class, however, may also come to be functionally substitutable for all other members of the equivalence class (Fields & Reeve, 2001; Fields, Reeve, Adams, Brown, & Verhave, 1997; Fields, Reeve, Adams, & Verhave, 1991). For example, a four-member equivalence class could consist of the word "marsh," a topographical map of terrain that includes a marsh, the orienteering symbol for a marsh, and a picture of a marsh. After training conditional discriminations that include word-map representations, map-symbol, and symbol-picture, all of the marsh representations may become substitutable for one another. This would demonstrate the formation of an equivalence class. In addition, we could also have a perceptual class consisting of variants of the marsh picture, an array of marsh pictures with increasing levels

of cloud cover. Some of these marsh picture variants could be substituted for any of the other members of the equivalence class and occasion class-consistent selection of all members of the equivalence class presented as comparisons. All of the stimuli that occasion class-consistent comparison selection would be members of the same stimulus class. This type of class, a merging of an equivalence class and stimuli that are related to members of the equivalence class by physical resemblance, is called a generalized equivalence class (Adams, Fields, & Verhave, 1993b; Fields, Adams, Buffington, Yang, & Verhave, 1996; Fields, Reeve, Adams, Brown, & Verhave, 1997; Fields, Reeve, Adams, & Verhave, 1991; Lane, Clow, Innis, & Critchfield, 1998; and Rehfeldt & Hayes, 2000).

Fields, Reeve, Adams, Brown, and Verhave (1997), demonstrated that membership of perceptual classes were predictive of membership of subsequent generalized equivalence classes. Each subject in that study formed two perceptual classes, one consisting of short line-lengths and the other consisting of long line-lengths. The short line-length class consisted of the lines that occasioned the selection of the 1-unit line as a comparison, and the long line-length class consisted of the lines that occasioned the selection of the 25-unit line as a comparison. Subjects then learned the AB, BC, and CD conditional discriminations, and passed all tests of emergent relations. The A, B, and C stimuli were nonsense syllables, and the D1 and D2 stimuli were the 1-unit and 25-unit lines, respectively. Generalization tests of emergent relations showed that line-lengths that were members of the short line-length perceptual class

functioned as members of Class 1, and line-lengths that were members of the long line-length perceptual class functioned as members of Class 2.

As mentioned above, the likelihood of equivalence class formation can be influenced by some variables that determine the structure of the class (Fields, Landon-Jimenez, Buffington, & Adams, 1995). To date, no studies have determined whether the structure of basal equivalence classes might influence the formation or extent of generalized equivalence classes. In addition, would different class structures influence the predictive relation that has been found between the widths of perceptual and generalized equivalence classes?

Response transfer across generalized equivalence classes. As discussed earlier, a response trained to one member of an equivalence class may be evoked by the remaining members of the equivalence class without additional discrimination training. Will generalized equivalence classes also act as response transfer networks? Only two experiments have examined the transfer of a response across the members of a generalized equivalence class (Barnes & Keenan, 1993); Fields, Adams, Buffington, Yang, & Verhave, 1996). Both of these experiments have methodological and/or interpretive shortcomings. In Barnes and Keenan (1993) the stimuli to which response transfer occurred shared common physical elements with the stimuli to which the responses were trained. In Fields, Adams, Buffington, Yang, and Verhave (1996), response transfer was demonstrated across stimuli that may have been related by transitivity, but not by equivalence.

In Barnes & Keenan (1993) two three-member equivalence classes were

established after the training of AB and AC relations. The structure of these classes can be represented symbolically as B<-A->C. The stimuli used in this experiment were consonant-vowel-consonant nonsense syllables. A multiple schedule of reinforcement for key pressing was then implemented with the B1 and B2 stimuli to establish different response rates. A DRL schedule was implemented in the presence of the B1 stimulus and a DRH schedule was implemented in the presence of the B2 stimulus. In unreinforced probe trials, all 8 subjects pressed the key at significantly higher rates for a stimulus that was a variant of C2 than a stimulus that was a variant of C1.

In Barnes and Keenan (1993), the stimuli used as basal members and the variants, however, were all consonant-vowel-consonant, nonsense syllables. Only one variant of one basal member was used in each class. The variants of the basal members consisted of the same two consonants as the basal members, except with different vowels. Thus, the identical components (either the first or last letter of the consonant-vowel-consonant sequence) might have occasioned the responses during the probe trials. If so, the transfer of responding to the new stimuli during the probe trials would not be a demonstration of response transfer. Rather, it would demonstrate the maintenance of responding controlled by elements of the training stimuli that were also present in the testing stimuli. Since the transfer of responding was measured to only one variant that shared common elements with the basal member, the results reported by Barnes and Keenan (1993) may not have demonstrated response transfer across members of a generalized equivalence class.

A more extensive study of response transfer across members of a generalized equivalence class was conducted by Fields, Adams, Buffington, Yang, and Verhave (1996). In their experiment, four college students formed two 4-member equivalence classes after training with the AB, BC, and CD conditional relations. The structure of these classes can be represented symbolically as $A \rightarrow B \rightarrow C \rightarrow D$. Each class consisted of 3 nonsense syllables (A, B, and C) and one line length (D). The D1 and D2 stimuli were composed of ASCII character strings which were 1 unit and 25 units in length, respectively. After forming the 2-node 4-member equivalence classes, variants of the D stimuli (D') were presented as samples with (D1 and D2), (C1 and C2), (B1 and B2), and (A1 and A2) pairs as comparisons. The D'-D trials assessed primary generalization, the D'-C trials assessed generalization of the symmetry relations, and the D'-B and D'-A trials assessed generalization of the equivalence relations. For each subject, stimuli from Class 1 were selected as comparisons when a particular set of variants of D were presented as samples, and stimuli from Class 2 were selected as comparisons when a complementary set of variants were presented as samples.

Successive discrimination training was then used to train different responses to the A stimuli in each class. In the presence of A1, pressing the "J" key five times before pressing enter was reinforced, and in the presence of A2, pressing the "J" key seven times before pressing enter was reinforced. The subjects were then exposed to the B, C, & D stimuli along with variants of the D stimuli, and required to make a J-key response. In general, subjects pressed the "J" key five times in the presence of B1, C1, and shorter line lengths, and pressed

the "J" key seven times in the presence of B2, C2, and longer line lengths. These performances showed that a response trained to one member of an equivalence class transferred to the other members of the class and to stimuli that were physically similar to the D member of the class (Fields, Adams, Buffington, Yang, & Verhave, 1996).

For all subjects, the range of line lengths that occasioned the 5J response included the same range of line lengths that occasioned the selection of all of the Class 1 stimuli in the generalization test of emergent relations. Likewise, the range of line lengths that occasioned the 7J response included the same range of line lengths that occasioned the selection of all of the Class 2 stimuli in the generalization test of emergent relations. This study demonstrated that the range of stimuli that were members of the generalized equivalence class was predictive of the range of stimuli that subsequently evoked a response that was trained in the presence of a member of the generalized equivalence class (Fields, Adams, Buffington, Yang, & Verhave, 1996). Thus, Fields et al. (1996) overcame the interpretive problem found in the Barnes and Keenan (1993) study.

The Fields et al. (1996) study, however, raised another theoretical issue. In Fields et al. (1996) the basal equivalence classes were established after the training of the AB, BC, and CD conditional relations. Specific responses were then reinforced in the presence of A1 and A2. Finally, the D stimuli including intermediate line lengths were presented without informative feedback. Response transfer was assessed across stimuli that could have been related by transitivity (response transfer from A to D). The response transfer, therefore, could be

accounted for by transitive relations and not equivalence relations. The Fields et al. study, then, did not unequivocally demonstrate response transfer among the members of a generalized equivalence class through equivalence.

Extending the analysis of response transfer. Fields et al. (1996) and Barnes and Keenan (1993) were the only two studies that assessed response transfer among members of generalized equivalence classes. Neither study, however, determined whether the range of variants that were members of perceptual classes formed prior to generalized equivalence classes would predict the range of stimuli that would occasion transfer of responding among the members of a generalized equivalence class.

In Fields et al. (1996) and Barnes and Keenan (1993), responses were trained to only one stimulus in each generalized equivalence class. A response, however, can be trained to any stimulus in a generalized equivalence class. To what extent would response transfer to all members of a generalized equivalence class depend on the stimulus to which the response was trained? If it is assumed that all members of a class are functionally interchangeable, this variable should not influence response transfer. Conversely, if it is assumed that structural variables influence the strength of relations among the members of an equivalence class and the strength of relations among the members of a perceptual class, one would predict that response transfer would vary with the stimulus to which the response is trained. The findings of the current study, then, should clarify how the functional relations among the stimuli in the classes are influenced by the underlying structure of the class.

Finally, Fields, Reeve, Adam, Buffington and Verhave (1997) showed that perceptual class width was an accurate predictor of generalized equivalence class membership. Likewise, Fields, Adams, Buffington, Yang, and Verhave (1996) showed that the range of stimuli that were members of generalized equivalence classes predicted response transfer among members of generalized equivalence classes. To date, however, perceptual class membership has not been used to predict likelihood of response transfer among the members of a generalized equivalence class.

Research Goals. The specific goals of the dissertation are to determine whether (a) transfer of responding among the members of a generalized equivalence class are supported by intervening equivalence relations, (b) transfer of responding varies with regard to the class member to which responses are trained, (c) the widths of perceptual classes are predictive of the widths of generalized equivalence classes and response transfer among those class members, (d) the number of functions served by nodal stimuli in generalized equivalence classes influences response transfer. These results, then, will provide a comprehensive documentation of some variables that influence response transfer among the members of generalized equivalence classes. At the level of basic processes, these results should clarify the effects of class structure on the strength of relations among the stimuli in generalized equivalence classes.

Generalized equivalence classes can be used as a model of the complex categories that are found in natural settings. Transfer of responding among the

members of such classes is an important phenomenon because it may well model the manner in which novel stimuli occasion appropriate actions in natural settings. The results of the current research, then, should provide a more comprehensive understanding of the development of complex naturally occurring categories and the transfer of responses among the stimuli in these categories.

Method

Subjects

The 15 subjects in the experiment were college students who received a combination of course credit and payment for their participation. The experiment took approximately 6 hours per subject, and this time was divided across three 2-hour sessions within a 2-week period. The allocation of payment was based on time spent as a subject, and was not based on performance. At the completion of the experiment, subjects were paid at a rate of \$10 per hour.

Subjects were randomly divided into three groups. Group 1 consisted of 3 subjects and Groups 2 and 3 both consisted of 6 subjects each. Unequal group sizes were used to balance the design with regard to the responses trained to class members, and will be discussed further in the Phase 5 section of the procedure. All groups were run concurrently. For each subject name, the first two letters identify the specific subject. The third character of the subject name identifies the group in which the subject was a member. Group 1 included subjects EW1, GD1, and HC1. Group 2 included subjects DA2, MK2, PM2, MT2, AH2, and EY2. Group 3 included subjects AE3, AB3, MM3, SD3, EV3, and AL3.

Apparatus

Hardware. The experiment was conducted using IBM compatible computers. The stimuli and directions were displayed on a 14 inch color computer monitor. Software developed to study equivalence classes and response transfer recorded all of the subjects' responses and trial information.

Stimuli. The experimental stimuli were satellite images of various 10 kilometer by 10 kilometer regions of the world provided by the Army Research Institute (see Figure 1). The stimuli used as basal members of Equivalence Classes 1 and 2 were labeled A, B, C, D, and E respectively. The stimuli used as perceptual variants of one member from each basal equivalence class were developed by morphing the E1 and E2 stimuli with image morphing software (Morph, Version 2.5, 1998), and are shown in Figure 2. The variants of the E stimuli were labeled with their respective position along the morph dimension between E1 and E2. The term "anchor" was used to designate the stimuli that were the endpoints of the morphed dimension. For the E dimension, E1 and E2 were the anchor stimuli.

Procedure

Phase 1: preliminary training. All subjects began the experiment with a preliminary training procedure that has been shown to induce broad perceptual classes (Fields, Wadhwa, Belanich, & Varelas, 2001). This procedure involved multiple exemplar training and testing with stimulus sets other than the experimental stimuli. A set of stimuli consisted of two endpoints and an array of 15 morphed variants created with Morph, Version 2.5 (1998).

First, subjects were tested to determine The extent to which they

spontaneously demonstrated broad perceptual classes during a 3-choice primary generalization test presented in a matching-to-sample format. A trial started with the presentation of the sample in the upper-middle of the screen. Pressing the space bar was required as an observing response to display the comparisons at the bottom of the screen. The sample remained at the top of the screen while the left and right comparisons were simultaneously presented at the bottom of the screen. In the primary generalization test, variants were presented as samples and the anchor stimuli were used as comparisons. During the preliminary training, subjects could select either the left or the right comparison stimuli by pressing the number 1 or 2 keys on the computer keyboard, respectively. Subjects could also select the neither comparison by pressing the number 4 key. The selection of the neither option indicated that a particular variant was not related to either of the anchor stimuli. The selection of the neither comparison in the presence of intermediate stimuli then allowed for the functional separation of classes (Fields, Adams, Buffington, Yang, & Verhave, 1996; Fields & Reeve, 2001; Innis, Lane, Miller, & Critchfield, 1998). Without a neither option, stimuli by default must be members of either one or the other class. The lack of a neither option forces the size of one class to increase as the size of the other class decreases. With a neither option, the size of one class does not necessarily dictate the size of the other class.

During training trials, after a subject selected a comparison informative feedback was presented. The words "RIGHT" or "WRONG" depending if the subject selected a class consistent comparison or not were used as feedback.

Pressing the "R" or "W" keys in the presence of "RIGHT" or "WRONG", respectively, removed the feedback from the screen and ended the trial. Each training block was repeated with 100% informative feedback until 100% correct responding was obtained. Based on previous research with similar procedures (Adams, Fields, & Verhave, 1993a; Fields, Reeve, Rosen, Varelas, Adams, Belanich, & Hobbie, 1997; and Fields, Varelas, Reeve, Belanich, Wadhwa, Derosse, & Rosen, 2000), it was assumed that informative feedback such as the word "RIGHT" displayed on the screen would reinforce the most recent comparison selection and the word "WRONG" displayed on the screen would punish the most recent comparison selection. To end a trial after the words "RIGHT" or "WRONG" were displayed, the subject was required to press the "R" or "W" keys, respectively. Feedback was then reduced to 75%, 25% and 0% during consecutive blocks if 100% correct responding was maintained. If a subject responded at a level of less than 100% correct, the level of reinforcement was repeated during the next block. If during a second block with a particular level of reduced feedback the subject again did not respond correctly on all trials, the next higher level of feedback was presented during the next block. When informative feedback was not presented following a response, the letter "E" was displayed on the screen to indicate the end of a trial. To end a trial after the letter "E" was displayed, pressing the "E" key was required.

A subject demonstrated the formation of a perceptual class when a broad gradient was obtained without informative feedback. A broad gradient was one in which at least the five variants adjacent to the anchor stimulus occasioned the

selection of the anchor stimulus during 88% of matching-to-sample trials for both classes. If a subject did not spontaneously demonstrate broad generalization gradients with a particular set, informative feedback was provided for the selection of comparisons that were consistent with broad generalization gradients. After a subject received training with a set and demonstrated maintenance of the broad gradient in the absence of feedback, another stimulus set was tested without feedback. For each set, training was provided if spontaneous broad perceptual classes were not demonstrated.

Only subjects who demonstrated spontaneous broad gradients in the absence of direct training with at least two sets of stimuli during Phase 1 continued with the experiment, and were exposed to Phase 2. Fifteen subjects completed Phase 1 and continued with the experiment. Eight subjects successfully completed Phase 1, but were used as pilot subjects to test the software and the experimental procedure. Thirteen subjects successfully completed Phase 1, but decided not to come back for the remaining phases of the experiment. Sixteen subjects did not successfully complete this screening procedure, and were not asked to return for the remaining phases of the experiment.

Phase 2: perceptual class formation. Next, a three-choice, primary generalization test was conducted with all of the E stimuli. These trials involved the presentation of variants of E as samples and E1 and E2 as comparisons. A neither option was also available as a comparison on all trials. The neither option provided the subject with an alternative response to end a trial without the

selection of either the E1 or E2 comparisons. As discussed earlier, the neither option allowed for the functional separation of Class 1 and Class 2.

The results from Phase 2 determined the specific stimuli that functioned as the boundary stimuli of respective perceptual classes. The variant that differed the most from the anchor stimulus (E1 or E2), and occasioned the selection of the class-consistent anchor stimulus during at least 88% of trials was labeled the boundary stimulus (E1b or E2b) for the respective class. The stimulus that was midway between E1b and E2b was labeled as En. All Eb, and En stimuli, then, were subject specific. These labels represented the functional properties of the stimuli for a particular subject.

Phase 3: equivalence class formation. In the present experiment, two 3-node, 5-member equivalence classes were established by each subject. The directionality of the conditional discriminations trained to Groups 1 and 2 differed from the directionality of the conditional discriminations trained to Group 3. In Groups 1 and 2, the classes were established by training AB, BC, CD, and DE conditional discriminations, yielding a structure represented by $A \rightarrow B \rightarrow C \rightarrow D \rightarrow E$. In Group 3, the classes were established by training AB, CB, CD, and ED conditional discriminations, yielding a structure represented by $A \rightarrow B \leftarrow C \rightarrow D \leftarrow E$.

To demonstrate equivalence class formation, subjects were required to pass all tests of emergent relations. For Groups 1 and 2, these tests included four symmetry probes (BA, CB, DC, and ED), three 1-node transitivity probes (AC, BD, and CE), three 1-node equivalence probes (CA, DB, and EC), two tests

of 2-node transitivity (AD and BE), two tests of 2-node equivalence (DA and EB), one test of 3-node transitivity (AE), and one test of 3-node equivalence (EA). For Group 3, the emergent relations tests included four symmetry probes (BA, BD, DC, and DE), six 1-node equivalence probes (AC, CA, BD, DB, EC and CE), four 2-node equivalence probes (DA, AD, BE, and EB), two 3-node equivalence probes (AE and EA).

All classes were established using the simple-to-complex (STC) procedure because it reliably leads to the formation of equivalence classes (Adams, Fields, & Verhave, 1993a; Fields, Reeve, Rosen, Varelas, Adams, Belanich, & Hobbie, 1997; and Fields, Varelas, Reeve, Belanich, Wadhwa, Derosse, & Rosen, 2000). The STC procedure involves a highly programmed sequence of training conditional discriminations interwoven with the presentation of tests of emergent relations. Only one pair of conditional discriminations are trained at a time. The "simple" emergent relations such as symmetry and transitivity must be successfully demonstrated before "complex" relations such as equivalence relations are tested. All relevant prerequisites must be demonstrated prior to each test type, and all relevant emergent relations must be demonstrated before training with a novel pair of conditional discriminations. For a more complete description of the STC procedure, see Adams, Fields, & Verhave (1993a).

Table 1 shows the sequences of training each conditional discrimination and testing with each emergent relations probe for both class structures. Each training block was repeated with 100% informative feedback until 100% correct responding was obtained. To end a trial after the words "RIGHT" or "WRONG"

were displayed, the subject was required to press the "R" or "W" keys, respectively. Feedback was then reduced to 75%, 25% and 0% during consecutive blocks if 100% correct responding was maintained. If a subject responded at a level of less than 100% correct, the level of reinforcement was repeated during the next block. If during a second block with a particular level of reduced feedback the subject again did not respond correctly on all trials, the next higher level of feedback was presented during the next block. When informative feedback (right or wrong) was not presented following a response, the letter "E" was displayed on the screen to indicate the end of a trial. To end a trial after the letter "E" was displayed, pressing the "E" key was required. A minimum of 4 blocks was needed to learn each baseline conditional relation. If a subject did not pass an emergent relation test in the first block, the block was repeated up to a maximum of six times or until the subject responded correctly during 100% of the trials in the block.

Phase 4: Emergence of generalized equivalence classes. After all tests of emergent relations were passed, the formation of two generalized equivalence classes was assessed with the same test for subjects in all groups. All of the variants of the E stimuli were presented as samples with the comparison pairs A1 and A2, B1 and B2, C1 and C2, D1 and D2, or E1 and E2, as shown at the bottom of Table 1. During these probes, the neither option was also available. Each trial type with each variant of E was presented 8 times over the course of 4 blocks of 170 trials each.

Phase 5: discrimination training. After the subjects' performance

documented the emergence of the generalized equivalence classes, they were trained to make three specific keyboarding responses in the presence of three different stimuli. The first block of discrimination training trials was preceded by an instruction screen which stated that during the following section a stimulus would be presented, and the subjects should press the "J" key X times (the specific number of J key presses for each group is presented below) or the "N" key 3 times and then press the "enter" key to end either response string. The responses will be referred to as XJ responses. For example, pressing the J key 5 times followed by pressing the "enter" key will be called a 5J response. Pressing the N key 3 times followed by pressing the "enter" key will be called the 3N response.

Figure 3 shows the structure of classes used in each group and the stimuli to which the responses were trained. In Group 1, reinforcement was provided for emitting the 5J response in the presence of A1 and the 9J response in the presence of A2. For half of the subjects in Group 2 (DA2, MK2, and PM2), reinforcement was provided for emitting the 3J response in the presence of E1a and the 7J response in the presence of E2b. For the other subjects in Group 2 (MT2, AH2, and EY2), reinforcement was provided for emitting the 3J response in the presence of E1b and the 7J response in the presence of E2a. For half of the subjects in Group 3 (AE3, AB3, and MM3), reinforcement was provided for emitting the 5J response in the presence of A1 and the 7J response in the presence of E2b. For the other subjects in Group 3 (SD3, EV3, and AL3), reinforcement was provided for emitting the 3J response in the presence of E1b

and the 9J response in the presence of A2. In all groups, reinforcement was also provided for emitting the 3N response in the presence of En.

All training was conducted with blocks containing 12 trials, four each for each of the three responses. All trials in a block were presented in a random order without replacement. During the first block of discrimination training, all responses were followed by feedback. Responses continued to receive 100% feedback until all stimuli in a block occasioned accurate responding. Feedback was reduced to 75%, 25%, then 0% on subsequent blocks if 100% accuracy was maintained in a block. If response accuracy was less than 100% correct, the level of feedback was maintained for two consecutive blocks. Thereafter, feedback was increased to the previous level. Training continued until subjects responded correctly on all trials during a block with no feedback.

Phase 6: response transfer test. All stimuli (A1, A2, B1, B2, C1, C2, D1, D2, E1, E2 and all 15 variants of E) were presented without feedback. The test consisted of each stimulus being presented 8 times over the course of 2 blocks. The trials within a block were presented in a random order without replacement. A trial began when a stimulus was presented, and ended when a subject pressed the "enter" key. The subject was free to press any combination of keys before pressing the "enter" key. The outcome of this test measured the likelihood of response transfer among all of the experimental stimuli.

Phase 7: assessment of discriminability. For a set of stimuli to be members of a class, they must occasion a common response, that response must not be occasioned by stimuli outside the set, and the stimuli within the set must be

discriminable from one another (Goldiamond, 1966; Wasserman, Kiedinger, & Bhatt, 1988; and Adams, Fields, & Verhave, 1993b). To assess discriminability, a few different variants were presented as samples, and the selection of a given comparison was reinforced with the presentation of the word "RIGHT" on the computer screen only if the selected comparison was identical to the sample. The selection of the neither comparison was reinforced during trials in which the sample stimulus was not identical to either of the comparisons. Selection of a non-identical sample occasioned the presentation of the word "WRONG" on the computer screen. Informative feedback was then reduced as previously described.

Specifically, the discriminability of the E variants was assessed over four stages. During the first stage, Ex1, Ex2, Ex3, Ex15, Ex16, and Ex17 were presented as samples while Ex1 and Ex17 were presented as comparisons. During the second stage, Ex2, Ex3, Ex4, Ex14, Ex15, and Ex16 were presented as samples while Ex2 and Ex16 were presented as comparisons. During the third stage, Ex3, Ex4, Ex5, Ex13, Ex14, and Ex15 were presented as samples while Ex3 and Ex15 were presented as comparisons. During the fourth stage, Ex4, Ex5, Ex6, Ex12, Ex13, and Ex14 were presented as samples while Ex4 and Ex14 were presented as comparisons. By selecting only the identical comparisons and selecting the neither option when comparisons that differed from the sample were presented, subjects indicated that adjacent stimuli along the continuum of variants were discriminable from one another.

A training block was repeated with 100% informative feedback until 100%

correct responding was obtained. Feedback was then reduced to 75%, 25% and 0% during consecutive blocks if 100% correct responding was maintained. If a subject responded at a level of less than 100% correct, the level of informative feedback was repeated during the next block. If during a second block with a particular level of reduced feedback the subject again did not respond correctly on all trials, the next higher level of feedback was presented during the next block.

Results and Discussion

Perceptual classes from primary generalization tests. The results of the primary generalization tests for all subjects are presented in Figures 4-6. The dotted horizontal line in each graph was at the 88% criterion level. The two dotted vertical lines in each graph indicate the variants that functioned as the boundaries for each perceptual class. Each vertical line demarcates the variant most distant from the anchor stimuli that occasions performances at or above the criterion level. The ordinate indicates the percentage of trials during which a subject selected particular comparisons in the presence of the variants of E that were presented as samples arrayed along the abscissa. The first column of graphs displays the percent of trials in which the subjects selected the E1 comparison given the variants of E presented as samples. The second column of graphs displays the percent of trials in which the subjects selected the neither option given the variants of E presented as samples. The third column of graphs displays the percent of trials in which the subjects selected the E2 comparison given the variants of E presented as samples.

For all subjects, the E1 stimulus was selected during at least 88% of trials in the presence of many variants with lower values of E_x , as shown in the first column of graphs. For each subject, the stimulus most distal to E1 that occasioned selection of the E1 comparison at criterion level was identified as E1b. In the presence of samples beyond E1b, the probability of selecting E1 decreased sharply while the probability of selecting the neither option increased in a complementary manner. While this occurred, there was essentially no selection of the E2 comparison. The range of stimuli that occasioned at least 88% selection of E1, then, were functioning as members of Perceptual Class 1.

For all subjects, the E2 stimulus was selected with a probability of 88% or greater in the presence of many variants with higher values of E_x , as shown in the third column of graphs. For each subject, the stimulus distal to E2 that occasioned selection of the E1 comparison at criterion level was identified as E2b. In the presence of samples beyond E2b, the probability of selecting E2 decreased while the probability of selecting the neither option increased in a complementary manner. While this occurred there was no essentially selection of the E1 comparison. The range of stimuli that occasioned at least 88% selection of E2, then, were functioning as members of Perceptual Class 2.

All subjects selected the neither comparison on at least 62% of trials in the presence of some intermediate values of E_x . Therefore, the performances used to document the width of Class 1 did not drive, by complementary measurement, the width of Class 2 or vice versa. It follows, then, that the widths of Perceptual Classes 1 and 2 were functionally independent of each other.

Perceptual class width. The performance of subjects during the primary generalization test can be used to determine the width of the perceptual classes. The width of a particular class was defined by the range of variants that occasioned selection of the same anchor stimulus during at least 88% of trials. The graph in Figure 7 shows the relative frequency of the widths of Perceptual Classes 1 and 2 obtained in Phase 2 for all subjects. All subjects were presented together, because up to this point in the experiment there were no procedural differences. Perceptual class widths were tightly clustered about a mean value of 6.2 variants with a standard deviation of 1.2.

Equivalence class formation. All subjects in all groups formed equivalence classes. Table 2 details the number of blocks needed to learn each conditional discrimination and pass each emergent relations test. Equivalence classes with the same structure were established with subjects in Groups 1 and 2. Therefore, the data for these subjects were combined for analysis.

A minimum of 4 blocks was required for the training of each baseline conditional discrimination. Each conditional discrimination was learned in an average of 6.3 blocks by the subjects in Groups 1 and 2, and an average of 10.6 blocks for subjects in Group 3. The difference in the number of blocks to acquire the baseline conditional discriminations by subjects in Groups 1 and 2 relative to Group 3 was statistically significant ($t = -2.6$, $df=13$, two-tailed $p = 0.04$) with the slower acquisition occurring for subjects in Group 3. A relatively large number of blocks were needed to acquire the conditional discriminations in Group 3, where each nodal stimulus served only one function. In Groups 1 and 2, however,

relatively few blocks were needed to acquire the conditional discriminations where all of the nodal stimuli served two behavioral functions. Thus, the number of trials needed to learn the conditional discriminations varied with the number of functions served by each nodal stimulus during training.

A minimum of one block was required to pass each of the 8 different emergent relations tests that were presented to evaluate the emergence of the equivalence classes. These tests were passed in an average of 1.5 blocks by the subjects in Groups 1 and 2, and an average of 1.4 blocks for subjects in Group 3. The difference in the number of blocks to pass the emergent relations tests was not statistically significant ($t = 0.54$, $df=13$, two-tailed $p=0.6$).

The training structures did not influence the likelihood of forming the 3-node 5-member equivalence classes or the speed of passing the emergent relations probes. In contrast, the training structures did have a significant effect on the overall number of trials needed for subjects to form equivalence classes. That difference was driven by the number of blocks, or speed, with which subjects acquired the conditional discriminations that were the prerequisites of the equivalence classes.

Generalized equivalence classes. Figure 8 shows the results of the generalization tests of all emergent relations for one subject, EW1. The dotted horizontal lines indicate the 88% criterion level, and the dotted vertical lines indicate the boundary variants for each perceptual class as determined during the primary generalization test in Phase 2. The ordinate indicates the percent of trials in which a subject selected a particular comparison, and the abscissa indicates

the variants that were presented as samples. The first column of graphs displays the percent of trials in which the subjects selected the comparisons from Class 1 given the variants of E presented as samples. The second column of graphs displays the percent of trials in which the subjects selected the neither option given the variants of E presented as samples. The third column of graphs displays the percent of trials in which the subjects selected the comparisons from Class 2 given the variants of E presented as samples. The top five rows of the figure show the results of a generalization test for each emergent relation (E'-E, E'-D, E'-C, E'-B, and E'-A) respectively. The bottom row shows the average functions of all generalization tests of emergent relations.

The top row of Figure 8 shows the results of the generalization test of reflexivity. Variants E1-Ex7 always occasioned the selection of the E1 comparison. Variants E2-Ex11 always occasioned the selection of the E2 comparison. Variants Ex8-Ex10 typically occasioned the selection of the neither option. The graphs in the next four rows show a similar pattern of comparison selection. Variants E1-Ex7 almost always occasioned the selection of D1, C1, B1 or A1 as comparisons. Variants E2-Ex12 always occasioned the selection of D2, C2, B2 or A2 as comparisons. Variants Ex7-Ex11 usually occasioned the selection of the neither option. Because these functions were consistent across test types, generalization gradients of emergent relations were averaged across the test types and are presented at the bottom of Figure 8. The performances depicted in the average generalization gradients of emergent relations accurately reflect the performances occasioned by the individual generalization tests of

emergent relations.

The results for individual generalization tests of emergent relations for the remaining subjects are included in Appendix A, and are quite similar to those presented in Figure 8. Therefore, the performances occasioned by the generalization tests of emergent relations were represented by averages taken across all of the generalization tests for emergent relations for each subject. Figures 9-11 show the averaged functions of the generalization tests of emergent relations for each subject in each experimental group.

For all subjects, the comparisons from Class 1 (A1, B1, C1, D1, and E1) were selected on at least 88% of trials when many variants of the lower values of Ex were presented as samples, as shown in the first column of graphs. In the presence of stimuli beyond the range of stimuli that regularly occasioned selection of the comparison from Class 1, the probability of selecting the Class 1 comparison decreased sharply while the probability of selecting the neither comparison increased in a complementary manner. As this change occurred, there was essentially no selection of the comparison from Class 2. The dimensional variants of the E stimuli that occasioned at least 88% selection of the comparisons from Equivalence Class 1 were functioning as members of Generalized Equivalence Class 1.

For all subjects, the comparisons from Class 2 (A2, B2, C2, D2, and E2) were selected on at least 88% of trials when many variants of the higher values of Ex were presented as samples, as shown in the last column of graphs. In the presence of stimuli beyond the range of stimuli that regularly occasioned

selection of the comparison from Class 2, the probability of selecting the Class 2 comparison decreased sharply while the probability of selecting the neither comparison increased in a complementary manner. As this change occurred, there was essentially no selection of the comparison from Class 1. The dimensional variants of the E stimuli that occasioned at least 88% selection of the comparisons from Equivalence Class 2 were functioning as members of Generalized Equivalence Class 2.

All subjects selected the neither comparison in the presence of some intermediate values of E_x , as shown in the middle column of graphs. Therefore, the width of Generalized Equivalence Class 1 did not drive, by complementary measurement, the width of Generalized Equivalence Class 2 and vice versa. The widths of both generalized equivalence classes, then, were functionally independent of each other.

Prediction of generalized equivalence class width from perceptual class width. Figure 12 depicts the widths of each generalized equivalence class for each subject plotted as a function of the width of the perceptual class that was included in the generalized equivalence class of which it was a component. The width of the perceptual class was measured prior to equivalence class formation. Each data point was for a separate subject and class. No differences were found between Class 1 and Class 2 across all subjects, therefore, the data for both classes were presented together. The top graph shows the results for the subjects in Group 1 and 2, while bottom graph shows the results for the subjects in Group 3. Groups 1 and 2 are presented together because the equivalence

classes had the same structure. Both graphs show positive correlations between the widths of the perceptual classes and the corresponding generalized equivalence classes (Groups 1 and 2 combined, $r=0.46$; Group 3, $r=0.68$). Thus, the width of a generalized equivalence class was predicted by the width of the perceptual class included in that class, which was measured before the linkage of the equivalence classes and the perceptual classes.

In some cases, the width of the perceptual class did not correspond exactly to the width of the generalized equivalence class. When that occurred, the direction of the disparity differed across groups. For Groups 1 and 2, if a disparity existed, the width of the perceptual class tended to underestimate the width of the corresponding generalized equivalence class. That is, the range of E variants that functioned as members of a generalized equivalence class exceeded the range of E variants that functioned as members of the corresponding perceptual class that had been linked to the basal equivalence class. For Group 3, however, if a disparity existed, the width of the perceptual class tended to underestimate the width of the generalized equivalence class. That is, the range of E variants that functioned as members of a generalized equivalence class was less than the range of E variants that functioned as members of the corresponding perceptual class that had been linked to the basal equivalence class.

To determine whether the over- and underestimations across the groups were significant, the differences between the width of a perceptual class and its corresponding generalized equivalence class were computed for both Class 1

and Class 2 for each subject in the two conditions: Groups 1 and 2 combined, and Group 3. The difference of the differences was found to be statistically significant ($t = -2.40$, $df = 28$, two-tailed $p = 0.024$). When the classes contained nodes that served two functions, the width of the perceptual class tended to underestimate the width of the generalized equivalence class. When the class contained nodes that served single functions, the width of the perceptual class tended to overestimate the width of the generalized equivalence class. Thus, the functions served by the nodal stimuli in the generalized equivalence class varied with the over- and underestimation of generalized equivalence class width

Discrimination training. In Phase 5, all subjects were taught to emit different keyboarding responses in the presence of particular stimuli. The bottom row of each section of Table 2 shows number of blocks each subject needed to learn these discriminations. To assess the influence of class structure on discrimination training, the results from Groups 1 and 2 were combined and then compared with the data obtained from the subjects in Group 3. A median of 6 blocks were needed to learn the discriminations for the subjects in Groups 1 and 2. A median of 10 blocks were needed to learn the discriminations for the subjects in Group 3. The difference between medians was statistically significant (Mann Whitney $U = 7.5$, two-tailed $p = 0.018$). The Mann Whitney U test was used because the data sets did not pass a test for the homogeneity of variance. The results indicate that the speed with which the discriminations were learned varied with the number of functions served by nodal stimuli in the generalized equivalence classes. This occurred even when the discriminanda were not

members of the basal equivalence classes, e.g., E1b or E2b.

Response transfer in generalized equivalence classes. Figures 13-15 display the results of the response transfer tests conducted after subjects learned the discriminations in Phase 5. The percentage of trials in which a particular response was evoked by specific stimuli is plotted as a function of each stimulus for each subject. The ordinate indicates the stimulus presented as the discriminative stimulus, and the abscissa indicates the percent of trials which occasioned a particular response. The first column of graphs shows the likelihood of the response trained to A1 in the presence of all stimuli. The second columns shows the likelihood of the response trained to En in the presence of all stimuli. The third column shows the likelihood of the response trained to A2 in the presence of all stimuli. The shaded bars represent trials in which basal equivalence class members were presented as the discriminative stimuli. The open circles represent trials in which variants of E were presented as the discriminative stimuli. Trials in which the E1 or E2 stimuli were presented as the discriminative stimulus are represented by both a shaded bar and an open circle because the E1 and E2 stimuli are members of both the basal equivalence classes and members of the perceptual classes. The vertical dotted lines represent the boundaries of the perceptual classes of E as defined during the primary generalization test in Phase 2. The horizontal dotted lines represent the 88% criterion level for membership in a generalized functional class. The arrows identify the stimulus to which a response was trained in Phase 5.

Figures 13 and 14 show the results for Groups 1 and 2, respectively.

Because classes with the same nodal functions were established in Groups 1 and 2, the response transfer data obtained for subjects in both groups are considered together. As shown by the graphs in the left column, the responses trained to one member of Generalized Equivalence Class 1, were also occasioned with similar likelihood by A1, B1, C1, D1, E1, and variants of E that extended to approximately E1b. This occurred for all subjects in Groups 1 and 2. The probability of producing the Class 1 response decreased sharply while the probability of producing the 'neither' response (3N) increased in a complementary manner when presented with stimuli beyond the range of stimuli that regularly occasioned the Class 1 response. As this change occurred, there was no evocation of the response trained to a member of Class 2. Since all of the members of the generalized equivalence classes occasioned the same response trained to one member of the same class, they were also acting as members of a generalized functional class.

As shown in the right column of graphs, the responses trained to one member of Generalized Equivalence Class 2, were also occasioned with similar likelihood by A2, B2, C2, D, E2, and variants of E that extended to approximately E2b. This occurred for all subjects in Groups 1 and 2.

The probability of producing the Class 2 response decreased sharply while the probability of producing the 3N response increased in a complementary manner when presented with stimuli beyond the range of stimuli that regularly occasioned the Class 2 response. As this change occurred, there was no evocation of the response trained to a member of Class 1. Since all of the

members of the generalized equivalence classes occasioned the same response trained to one member of the same class, they were also acting as members of a generalized functional class.

For the subjects in Groups 1 and 2, some of the intermediate values of Ex evoked the 3N response with very high probabilities, as shown in the graphs in the middle column of Figures 13 and 14. Therefore, ranges of stimuli that were members of Generalized Functional Classes 1 and 2 were independent of each other.

Subjects in Group 3 showed a very different overall outcome in the response transfer tests. The results for subjects in Group 3 are presented in Figure 15. Three of the six subjects (AE3, AB3, and MM3) showed response transfer from the A and Eb stimuli that was like that shown for all of the subjects in Groups 1 and 2. The responses trained to these stimuli transferred completely to all of the remaining stimuli in their respective classes.

In contrast, the three remaining subjects from Group 3 (SD3, EV3, and AL3), did not show systematic transfer of responding. Instead, these subjects showed breakdowns of the trained Sd-response relations, greatly truncated response transfer, or a complete lack of response transfer. Specifically, the responses trained to EB1 for subjects SD3 and AL3 were occasioned by only the other members of the perceptual class, and were not occasioned by members of the linked equivalence class. The response trained to A2 for subject SD3 was occasioned by A2 during the test blocks, but was only occasioned by the remaining members of the generalized equivalence class at less than criterion

level. The responses trained to EB2 and A2 for subject EV3 were occasioned by sets of stimuli beyond their respective generalized equivalence classes. Finally, the response trained to A2 for subject AL3 was rarely occasioned by any of the stimuli presented during the response transfer test. These results show that the subjects who demonstrated a lack of response transfer among members of generalized equivalence classes did not show any consistent patterns of response transfer.

Untrained responses in transfer tests. The graphs in Figures 13-15 included the data for the responses that were used in discrimination training only. A summation of the percentages of the trained responses occasioned by each test stimulus indicated that untrained responses occurred very infrequently. Twelve of the 15 subjects made errors on 0.5 to 4% of the trials. Subject AB3, AH2 and AL3 made errors on 5.5%, 7.5% and 21% of the trials, respectively. The errors included J strings of 2-10 key presses in length or strings of 2-4 N key presses. On occasion any of these strings was intermixed with 1-3 other keys. For a complete presentation of every error each subject made, see Appendix B.

Effects of training stimuli and nodal functions on response transfer. The data obtained in the response transfer tests illustrated how response transfer was influenced by two factors: the stimuli to which a response was trained, and the behavioral functions served by nodal stimuli in each generalized equivalence class.

First, to what extent does response transfer vary with the stimulus to which a response was trained? In Group 1, responses were trained to the A stimuli in

both classes, in Group 2 responses were trained to stimulus Ea in one class and stimulus Eb in the other class, and in Group 3 responses were trained to stimulus A in one class and stimulus Eb in the other class. Figure 16 shows that the range of variants that were members of the generalized functional classes when responses were trained to each of the above mentioned class members. Figure 16 includes the data from subjects who demonstrated response transfer among members of generalized equivalence classes. The data for subjects who did not show systematic response transfer were excluded because it was not possible to obtain accurate measures of response transfer.

The top, middle, and bottom graphs show the widths of generalized functional classes for classes established after training a response to the A, Ea, and Eb stimuli in the generalized equivalence classes. The overlapping distributions were not significantly different (Kruskal-Wallis, $p=0.18$). The Kruskal-Wallis test was conducted because the data sets did not pass a test for the homogeneity of variance. Therefore, the likelihood and extent of response transfer was not influenced by the stimulus to which a response was trained. Each generalized equivalence class, then, was acting as a function transfer network.

Second, the classes formed in Groups 1 and 2 contained nodal stimuli that served two behavioral functions. In Group 3, each nodal stimulus in a class served only one behavioral function. Response transfer occurred with 9 of 9 subjects in Groups 1 and 2, and 3 of 6 subjects in Group 3. This difference was significant (Chi Square=5.6, $df=1$, $p = 0.01$). Therefore, the likelihood of

successful transfer of function across members of a generalized equivalence class varied with the number of functions served by the nodal stimuli in a class.

Additional research would be needed to determine the extent to which the number of functions served by nodal stimuli exert a systematic effect on the transfer of responding among the members of a generalized equivalence class. The approach can be illustrated by considering a 3-node 5-member equivalence class. Since the class contains three nodal stimuli, zero to three nodes can serve dual functions. At one end of the continuum, a class could have three dual function nodes by training AB, BC, CD, and DE, yielding a class with an A→B→C→D→E structure. A class with an A→B→C←D←E structure, established by training AB, BC, DC, and ED, would have two nodes (B and D) which serve two functions and one nodes (C) which serves a single function could be established. A class with an A→B→C←D→E structure, established by training AB, BC, DC, and DE, would have one node (B) which serves two functions and the other two nodes (C and D) would serve single functions. Finally, a class with an A→B←C→D←E structure, established by training AB, CB, CD, and ED, would have no nodes serving two functions and all three nodes would serve only one function. Differences in the transfer of responding among the generalized equivalence classes containing these nodal structures would demonstrate the suggested functional relationship that might exist between response transfer and nodal function.

Predicting generalized functional class width. The scattergrams in the left and right columns of Figure 17 compare the widths of generalized functional

classes with their corresponding perceptual classes and generalized equivalence classes, respectively. The first, second, and third rows show the results for Groups 1, 2, and 3, respectively. Data for Group 3 were for the subjects who formed generalized functional classes.

The width of a generalized functional class was positively correlated with the width of its related perceptual and generalized equivalence class. For the left column of graphs, the correlation coefficients were 0.71, 0.76, and 0.88 for Groups 1, 2, and 3, respectively. For the right column of graphs, the correlation coefficients were 0.94, 0.30, and 0.91 for Groups 1, 2, and 3, respectively. The widths of the generalized functional classes, then, were predicted by the widths of the corresponding perceptual and generalized equivalence classes. This was found regardless of the functions served by the nodal stimuli in each class, and the stimulus to which a response was trained.

Predicting failure of response transfer. The failure of response transfer was rather unexpected. Therefore, a post-hoc analysis was conducted to determine whether that failure was correlated with some prior test performance. All of the subjects who failed response transfer also showed shrinkage from the range of E-variants that functioned as members of the perceptual class to the range of E-variants that were members of at least one generalized equivalence class (3 of 3). In contrast, such a shrinkage in class size was shown by only 2 of the 12 subjects who demonstrated response transfer. This difference was statistically significant (Chi square=7.5, df=1, p=0.006). Thus, failed response transfer among members of a generalized equivalence class was predicted by a

shrinkage in the range of perceptual class members that came to function as members of a generalized equivalence class.

Discriminability. Table 4 shows the number of training blocks required to complete each stage of discriminability training. At least four blocks were programmed to complete training in each stage. Actual performances on each block of discriminability training are presented in Appendix C.

During Stage 1, a median of 7 blocks, three more than the minimum, were needed to reach the criterion indicating complete discrimination of the two anchor stimuli (Ex1 and Ex17) from each other and from the three variants that were most similar to each anchor stimulus. An accuracy level of at least 75% correct occurred on the first training block for 5 subjects, and was attained on the second or third training block for 6 subjects, and on the fourth to sixth training block for 3 subjects. One subjects reached this performance level on the twelfth training block. Thus, most subjects showed relatively high levels of discriminative control by adjacent stimuli with little training. Thereafter, 100% accuracy was achieved in very few additional training blocks, and eventually all subjects showed complete discrimination among adjacent stimuli.

During Stage 2, a median of 5 blocks, one more than the minimum, were needed to discriminate Ex2 and Ex16 from each other and from Ex3, Ex4, Ex5, Ex13, Ex14, and Ex15. In Stage 3, 14 of the 15 subjects showed complete accuracy in performance in the first or second training block. In Stage 4, all of the subjects showed complete accuracy in performance in the first or second training block. To summarize, the immediately adjacent E-variants used in Stages 2-4

were discriminated from each other with little or no training.

General Discussion

Merger of perceptual and equivalence classes. A set of stimuli that occupies a region along some continuum is functioning as a perceptual or open ended stimulus class when three criteria are satisfied: (a) a given response is evoked by all of the stimuli in the region, after the response has been trained to occur in the presence of only some of them, (b) the same response is not evoked by stimuli that occupy another nonoverlapping region of the dimension, and (c) some or most of the stimuli in the set are discriminable from one another. In the current experiment, the response was conditional selection of a given comparison stimulus. During the primary generalization tests, the selection of a given comparison was occasioned by many of the contiguous stimuli at one end of the morphed dimension. That comparison was not selected in the presence of the stimuli at the other end of the dimension. During discriminability assessment, subjects responded differentially to many adjacent stimuli along the morphed dimension with little or no training. These performances, then, satisfy the three criteria needed to conclude that a set of stimuli were functioning as members of a perceptual class of discriminable stimuli.

It could be argued that the stimuli in Perceptual Classes E1 and E2 became discriminable from each other after the training conducted in the discriminability assessment phase of the experiment. If so, the stimuli in the perceptual class might not have been discriminable from each other during the assessment of class emergence. This hypothesis, however, is not supported by

the data shown in Table 3. In most cases, high levels of differential responding occurred at the start of each phase of discriminability training. In many cases, at the start of training in Phases 2-4 of discriminability training, adjacent stimuli spontaneously occasioned differential responding, even though they had occasioned reinforcement for the selection of same response in the preceding stage. For example, in Phase 1, Ex2 and Ex3 occasioned reinforcement for selection of the neither comparison. At the start of phase two, Ex2 occasioned reinforcement for selection of Ex2 while Ex3 occasioned reinforcement for selection of the neither comparison. In this phase, subjects immediately discriminated between the stimuli. These findings support the view that the E variants were discriminable from each other before the start of discriminability training. This implies that the stimuli in each perceptual class were discriminable from each other as the classes were being formed. At most, the effect of discriminability training was to sharpen already established discriminations among the variants of the E stimuli. It also follows from this interpretation that the performances occasioned by the generalization tests of emergent relations reflected a merger of a perceptual class with an equivalence class that shared the common stimulus, Ea.

Predictability of class membership. Fields, Reeve, Adams, and Verhave (1991) and Fields, Reeve, Adams, Brown, and Verhave (1997) showed that perceptual class width was an accurate predictor of generalized equivalence class membership. Fields, Adams, Buffington, Yang, and Verhave (1996) showed that the range of stimuli that were members of generalized equivalence classes

was an accurate predictor of response transfer among members of generalized equivalence classes. Prior studies, however, have not determined whether perceptual class width would be an accurate predictor of response transfer among the members of a generalized equivalence class. The results of the current study showed all three predictive relationships. The fact that performances occasioned by the stimuli in a perceptual class are predictive of the performances during generalization tests of emergent relations and response transfer tests supports the view that a generalized equivalence class consist of functionally interchangeable stimuli that act as a transfer network.

Acquisition of conditional and simple discriminations. The speed of learning the conditional discriminations that were the prerequisites of the equivalence classes was influenced by the number of behavioral functions served by the nodal stimuli in those conditional discriminations. Some recent studies have also shown that conditional discrimination learning was influenced by the behavioral functions served by nodal stimuli in conditional discrimination training. Specifically, conditional discriminations that contained single nodes were acquired fastest when the nodal stimulus served as a comparison, at an intermediate rate when the nodal stimulus served as a sample, and most slowly when the nodal stimulus served as a sample in some conditonal discriminations and as a comparison in others, i.e., when the nodal stimuli served two behavioral functions (Fields, Hobbie, Reeve, & Adams, (2000; Saunders, Drake, & Spradlin, 1999). In the current study, however, the speed of acquiring conditional discriminations was faster when the nodal stimuli served two behavioral functions rather than

one.

When conditional discriminations share only one nodal stimulus, the Saunders and Green (1999) discrimination analysis provides a clear account of the effects of nodal stimuli that serve different behavioral functions. In the current study, however, the functions served by nodal stimuli do not bear the same correlation with speed of acquisition. Therefore, the Saunders and Green analysis would have to be modified in a substantive manner to account for the data obtained in the current experiment (Fields, Hobbies, et al., 1999).

In addition to influencing speed of learning conditional discriminations, the number of functions served by the nodal stimuli in the generalized equivalence classes also influenced the speed of learning the simple discriminations. Acquisition speed of the simple discriminations was slower for Group 3 than for Groups 1 & 2. Group 3 consisted of classes with single function nodes and Groups 1 and 2 consisted of classes with with dual function nodes. Thus, the number of functions served by the nodal stimuli in the classes had the same effect on the speed of learning both these simple discriminations and the conditional discriminations.

The effect of nodal function occurred even though the nodes in the class (B, C and D) did not serve as the discriminanda (A, Ea and Eb) in the simple discriminations. It would appear, then, that the functions served by the nodes in a class (B, C and D) transferred to the non-nodal members of the classes (A, Ea and Eb) and influenced the ability of the latter stimuli to acquire discriminative control of responding.

Generality of response transfer. The two prior experiments that studied response transfer among members of generalized equivalence classes trained the responses to the same nominal stimulus (e.g., A1 and A2) in all classes (Barnes & Keenan, 1993; and Fields et al., 1996). Response transfer, however, can take place from any stimulus in a class to all other class members. Therefore, the previously gathered data did not indicate whether response transfer would be influenced by the class member to which the response was trained.

In the present experiment, responses were trained to the A, Ea, or Eb stimuli in a generalized equivalence class. Further, in Groups 2 and 3, responses were trained to different stimuli in different classes on a concurrent basis. For 12 of 15 subjects, a response was evoked by all members of the generalized equivalence class, regardless of the stimulus to which it was trained. These data, then, demonstrate, on a within subject basis, that a generalized equivalence class acts as a function transfer network. Thus, the shortcomings present in the prior research was overcome in the current experiment.

The variants that were beyond the boundary stimulus for each generalized equivalence class rarely occasioned the response trained to class members A, Ea or Eb. Indeed, the edges of the response transfer function were equally steep regardless of the stimulus to which a response was trained. According to simple stimulus generalization, the transfer of responding to the stimuli beyond the boundary variant of a class (between Eb and En) should be greatest when the response is trained to the boundary stimulus (Eb), less when the response is

trained to the anchor stimulus (Ea) which is more distant from the variants that are not members of Classes 1 or 2, and least when the response is trained to the A stimulus in the basal equivalence class. That, however, was not the case. Minimal transfer occurred to the stimuli beyond Eb in all cases. Thus, response transfer among the members of a generalized equivalence class appears to be controlled predominantly by class membership and minimally by the dimensional similarities of the stimuli along the E dimension.

Several different behavioral functions, such as simple discriminations (de Rose, McIlvane, Dube, Galpin, & Stoddard, 1988), ordinal functions (Green Sigurdardottir, & Saunders, 1991; Sigurdardottir, Green, & Saunders, 1990; Wulfert & Hayes, 1988), reinforcement and punishment (Hayes, Kohlenberg, & Hayes, 1991), and conditional discriminations (Gatch & Osborne, 1989; Lynch & Green, 1991) have been acquired by one stimulus in an equivalence class then transferred to other members of the class. The transfer of these functions among the members of generalized equivalence classes has not been studied. The testing strategy described above could be used for this purpose to assess the generality of function transfer in generalized equivalence classes.

Possible determinants of response transfer performances. A number of variables were correlated with the likelihood of response transfer. These include the particular stimuli to which responses were trained, the particular response topographies trained to the stimuli, and the number of functions served by the nodal stimuli in the classes. Theoretically, any or all of these parameters could be responsible for the differential outcomes of response transfer seen in the study.

Each will be considered in order.

First, for the subjects in group 3 who demonstrated response transfer, responses were trained to occur in the presence of A1 and E2b . In contrast, for the subjects in group 3 who failed to demonstrate response transfer, responses were trained to occur in the presence of A2 and E1b. Therefore, it could be argued that the unique stimuli to which the responses were trained were responsible for differences in the likelihood of response transfer. This account is implausible for the following reasons. In groups 1 and 2, no differences in response transfer were observed when responses were trained to occur in the presence of A1, A2, E1b, and E2b. These were the same stimuli to which the responses were trained in Group 3. Therefore, there is no basis for assuming that the stimuli to which the responses were trained would be responsible for the differences in response transfer seen across subjects in Group 3.

Second, for the subjects in group 3 who demonstrated response transfer, 5J and 7J responses were trained to occur in the presence of A1 and E2b, respectively . In contrast, for the subjects in group 3 who failed to demonstrate response transfer, 3J and 9J responses were trained to occur in the presence of A2 and E1b, respectively. Therefore, it could be argued that the unique responses that were trained to occur in the presence of the A and Eb stimuli were responsible for differences in the likelihood of response transfer. This account is implausible for the following reasons. In Groups 1 and 2, subjects were trained to emit the 3J and 9J responses in the presence of the A and Eb stimuli and all subjects showed successful response transfer. These were the same response

that were trained to occur in the presence of the A and Eb stimuli in Group 3.

Therefore, there is no basis for assuming that the specific response topographies were responsible for the differences in response transfer seen across subjects in Group 3.

By elimination, then, the only remaining parameter that could account for the differential response transfer effect is the number of functions served by the nodes in the generalized equivalence classes. This parameter will be considered in the next section.

Determinants of response transfer and class shrinkage: an explanatory model. All of the subjects in Groups 1 and 2 showed full merger of a perceptual and linked equivalence classes as well as the transfer of responding from one member of a generalized equivalence class to all others. Only half of the subjects in Group 3 showed class-consistent transfer of responding among the members of generalized equivalence classes. For these subjects, only a portion of each perceptual class came to function as a member of its linked equivalence class. Therefore, a failure of response transfer was foreshadowed by a truncation in the membership of a generalized equivalence class.

The classes established in Groups 1 and 2 contained nodal stimuli that served two behavioral functions. The classes established in Group 3 contained nodal stimuli each of which served only one behavioral function. Therefore, restricted class merger and failed response transfer were both correlated with classes that contained nodes that served single functions, while full class mergers and successful response transfer were correlated with classes that

contained nodes that served two functions. To summarize, failed response transfer among members of a generalized equivalence class, and restricted extension of class size both varied with the number of behavioral functions served by the nodes during conditional discrimination training.

All of these results can be accounted for by making two assumptions. First, the strength of the relations among the stimuli in an equivalence class is influenced by the number of functions served by nodal stimuli in the class. Second, the strength of the relations among the members of an equivalence class will be challenged incrementally by the addition of new operations. Thus, a given number of operations will be more likely to produce flaws in new test performance for classes that contain nodal stimuli that serve one rather than two functions.

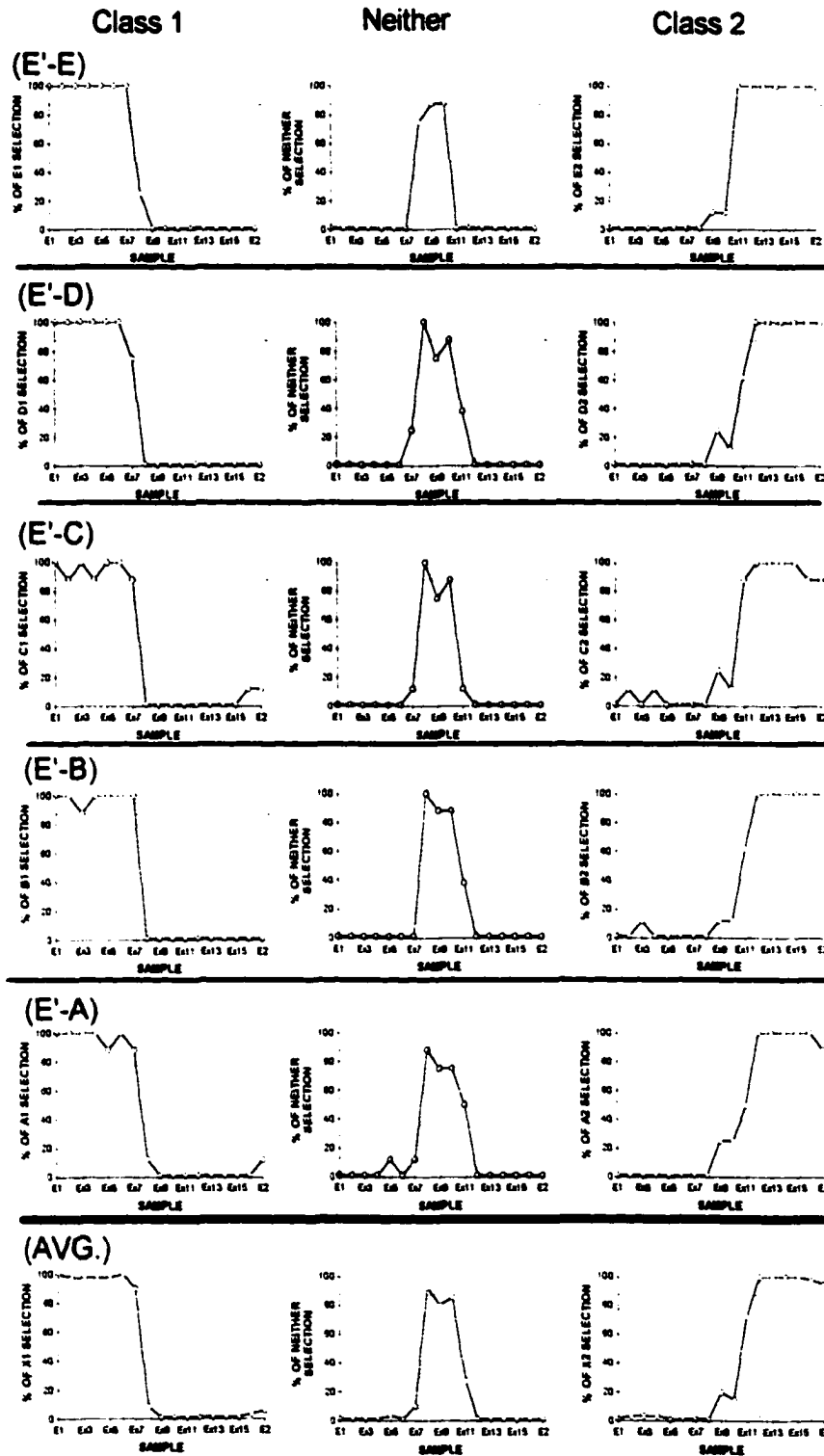
In the current experiment, the first operation was the generalization test of emergent relations that assessed the merger of the perceptual and its' linked equivalence class. The weaker relations among the stimuli in the classes containing single function nodes was manifested by a reduction in the range of perceptual class members that came to function as members of the generalized equivalence class. The second operation was the response transfer test that assessed the evocation of the same response by the remaining members of the generalized equivalence class. The weaker relations among the stimuli in the classes established by subjects in Group 3 was manifested by an increase in failed response transfer test performances.

To summarize, the strength of the relations among the stimuli in an

equivalence class can be assessed by requiring new performances that rely on class integrity. Each new performance is defined by the addition of an new experimental operation. Each of these operations can be viewed as an incremental challenge to the integrity of the stimulus-stimulus relations in the underlying equivalence classes. When classes are established with different structures, differential disruptions in new test performances then show how a particular training structure influences the strength of the relations among the member of the class.

GENERALIZED EMERGENT RELATIONS
Subject - EW1

Appendix A



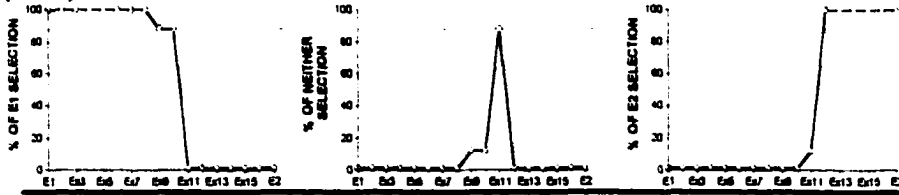
Subject - GD1

Class 1

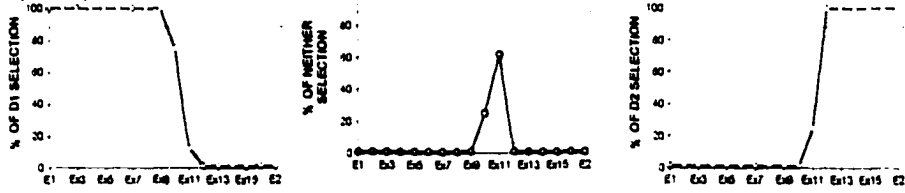
Neither

Appendix A - continued
Class 2

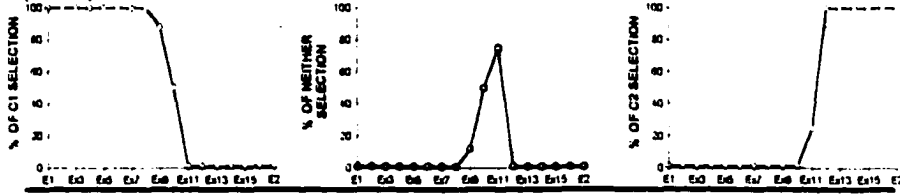
(E-E)



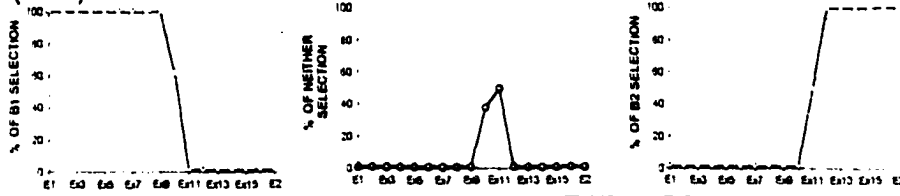
(E-D)



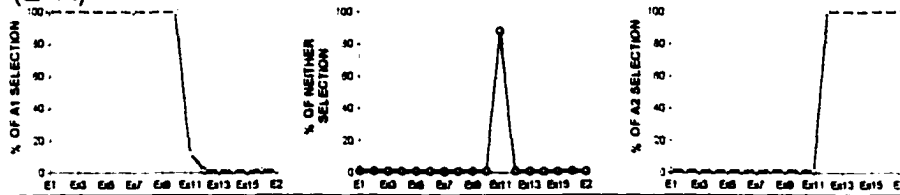
(E-C)



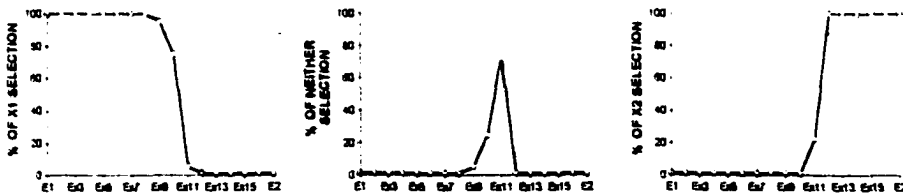
(E-B)



(E-A)



(AVG.)



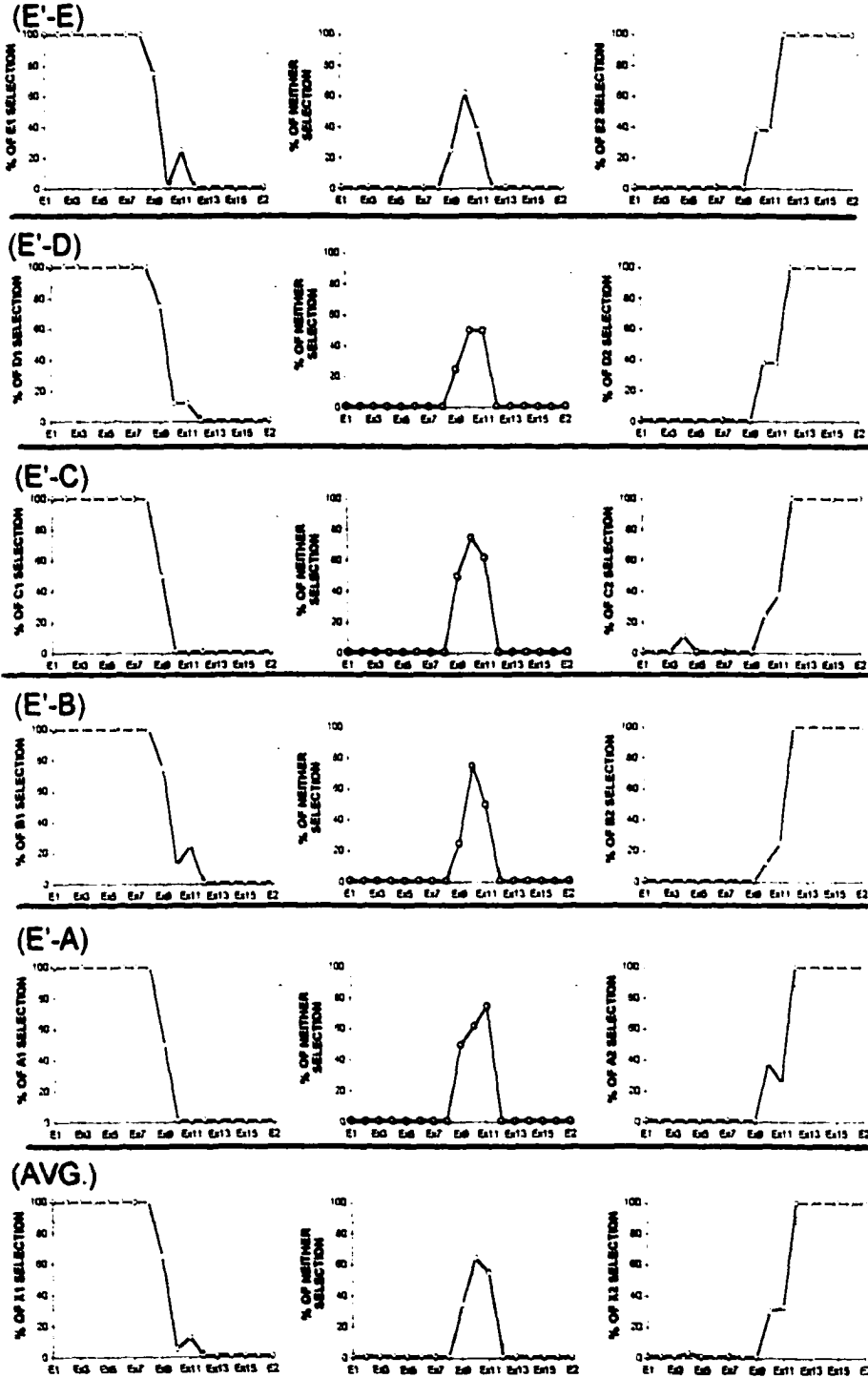
Subject - HC1

Appendix A - continued

Class 1

Neither

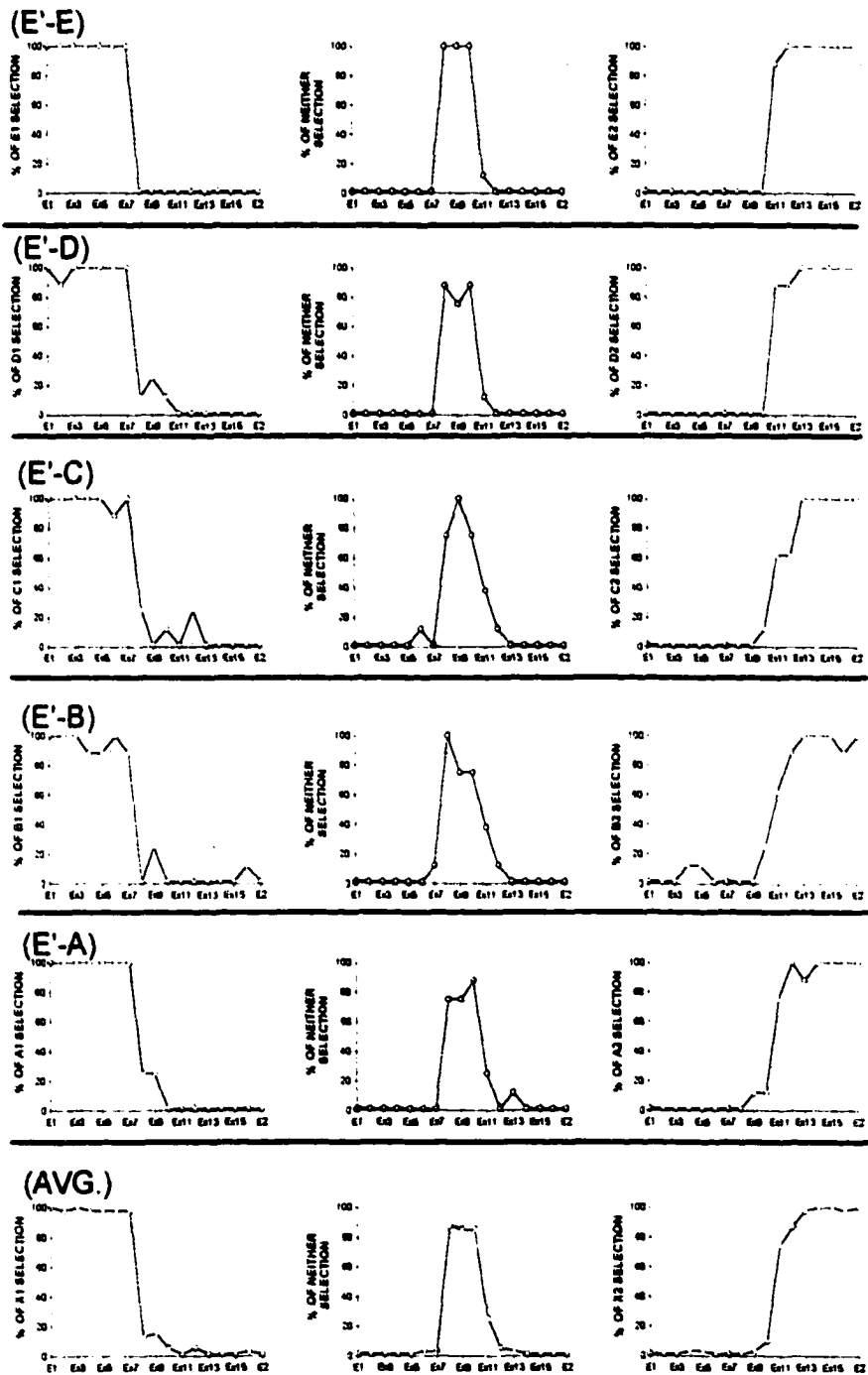
Class 2



Subject - PM2
Class 1

Neither

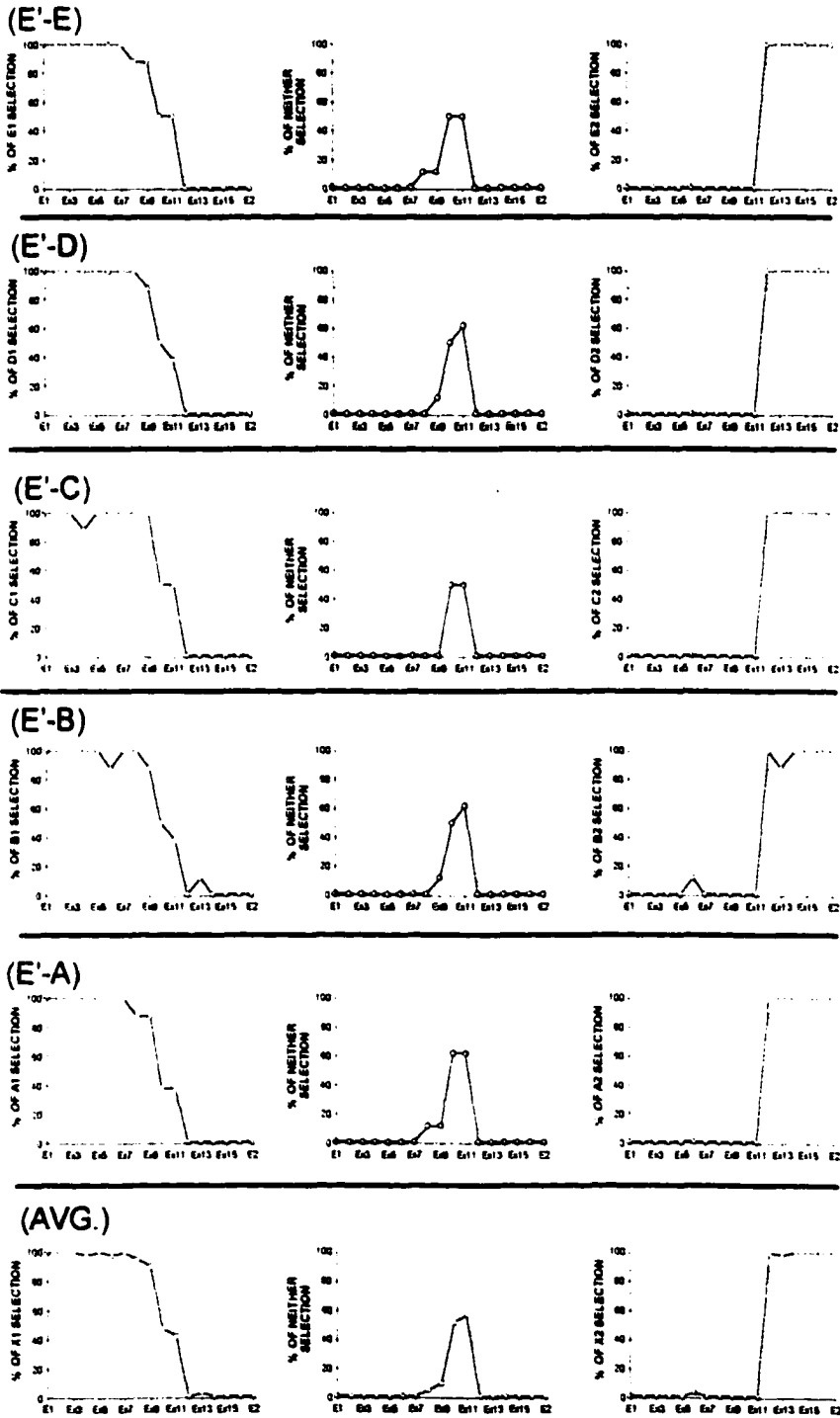
Class 2



Subject - MK2
Class 1

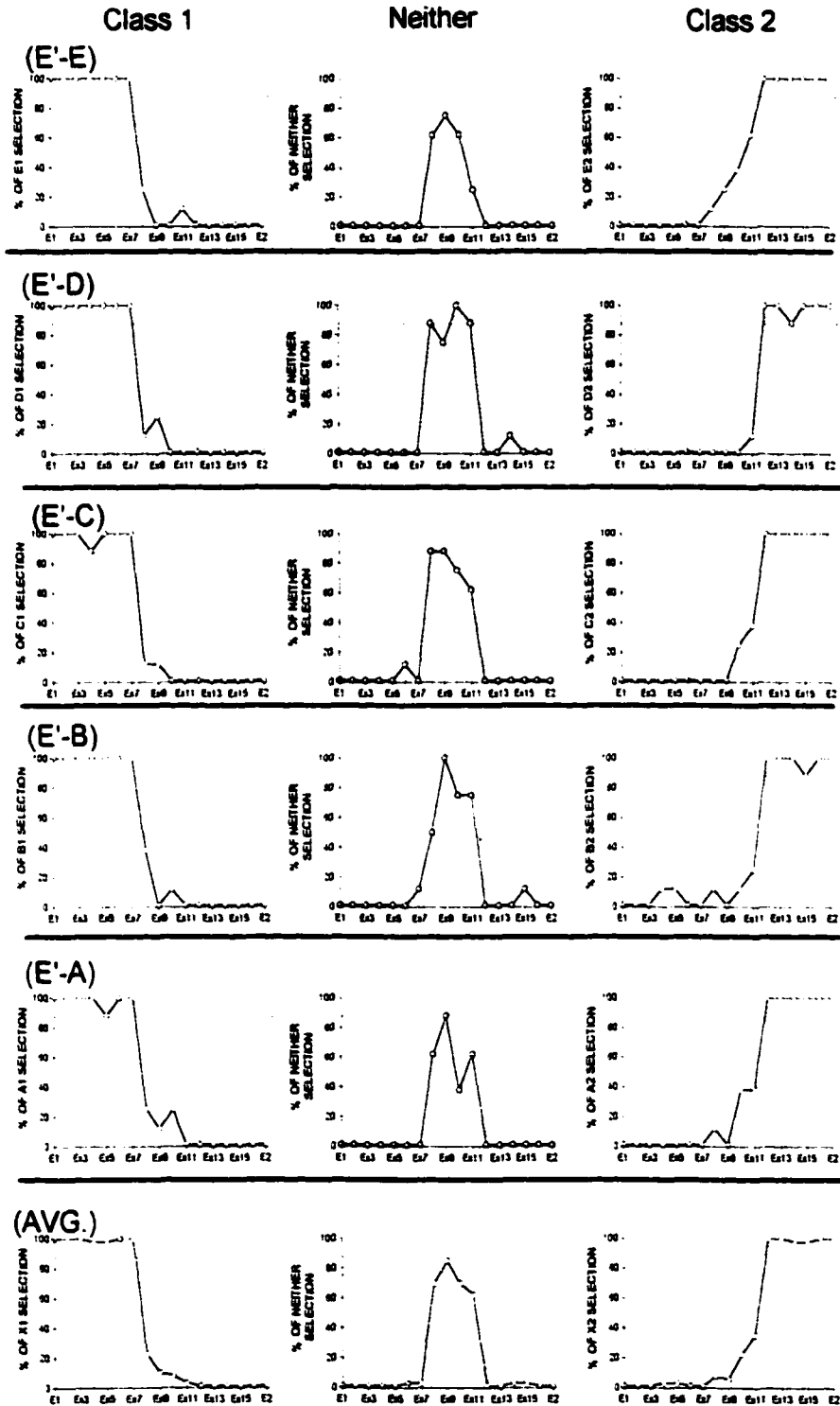
Neither

Appendix A - continued
Class 2



Subject - DA2

Appendix A - continued



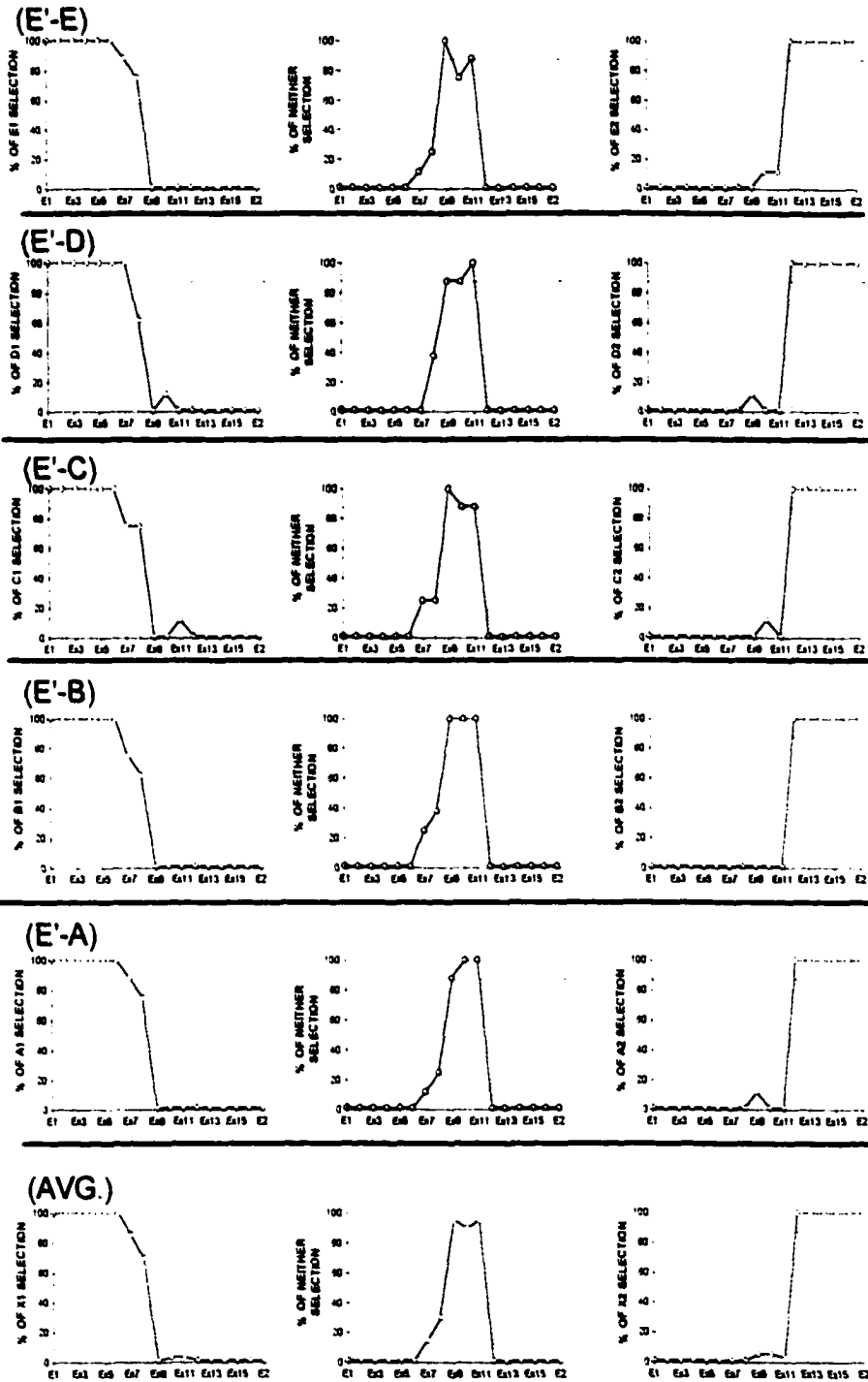
Subject - MT2

Appendix A - continued

Class 1

Neither

Class 2

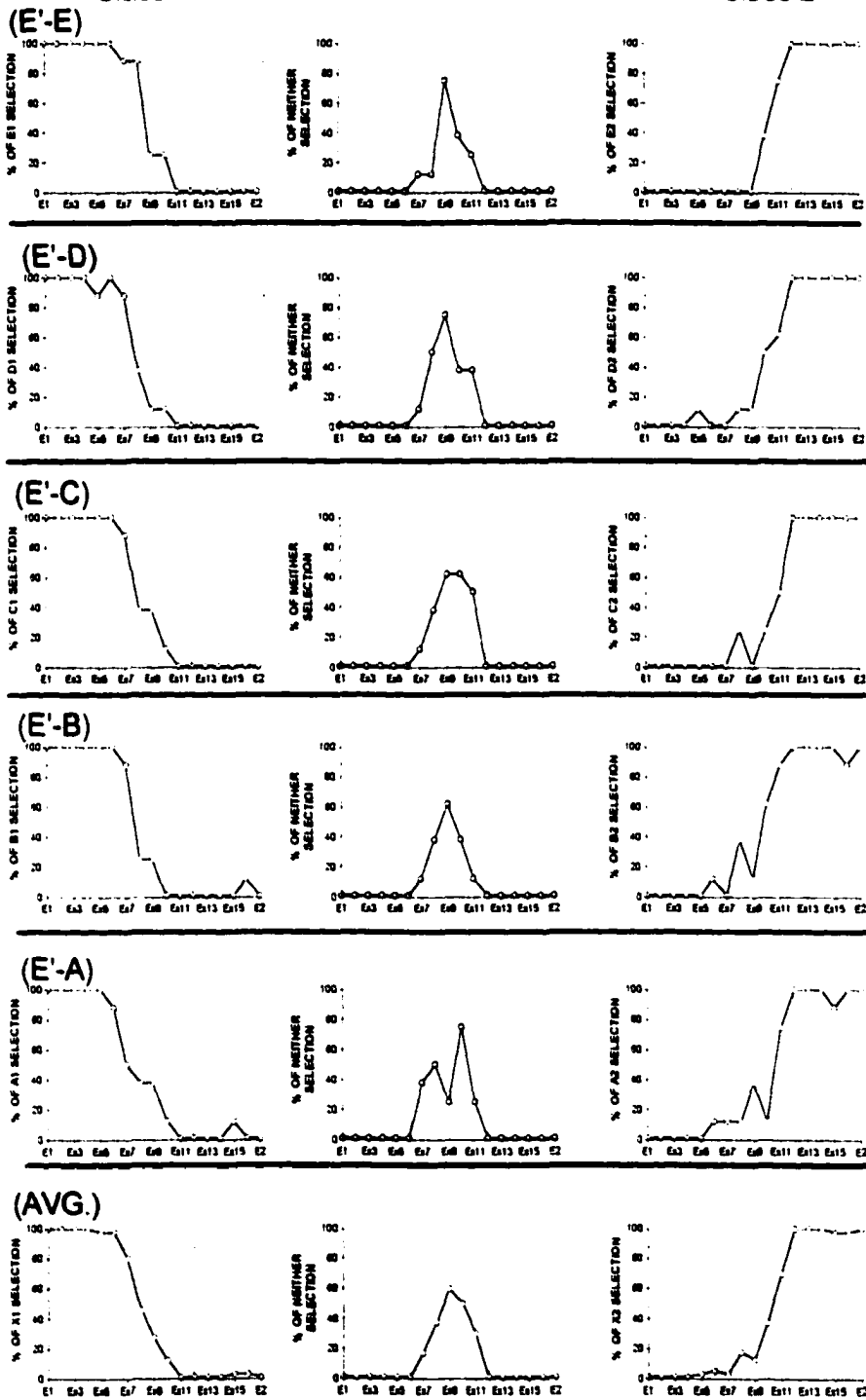


Subject - AH2

Class 1

Neither

Class 2



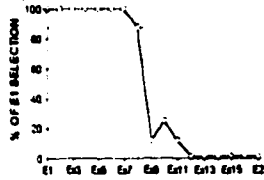
Subject - MT2

Class 1

Neither

Class 2

(E'-E)



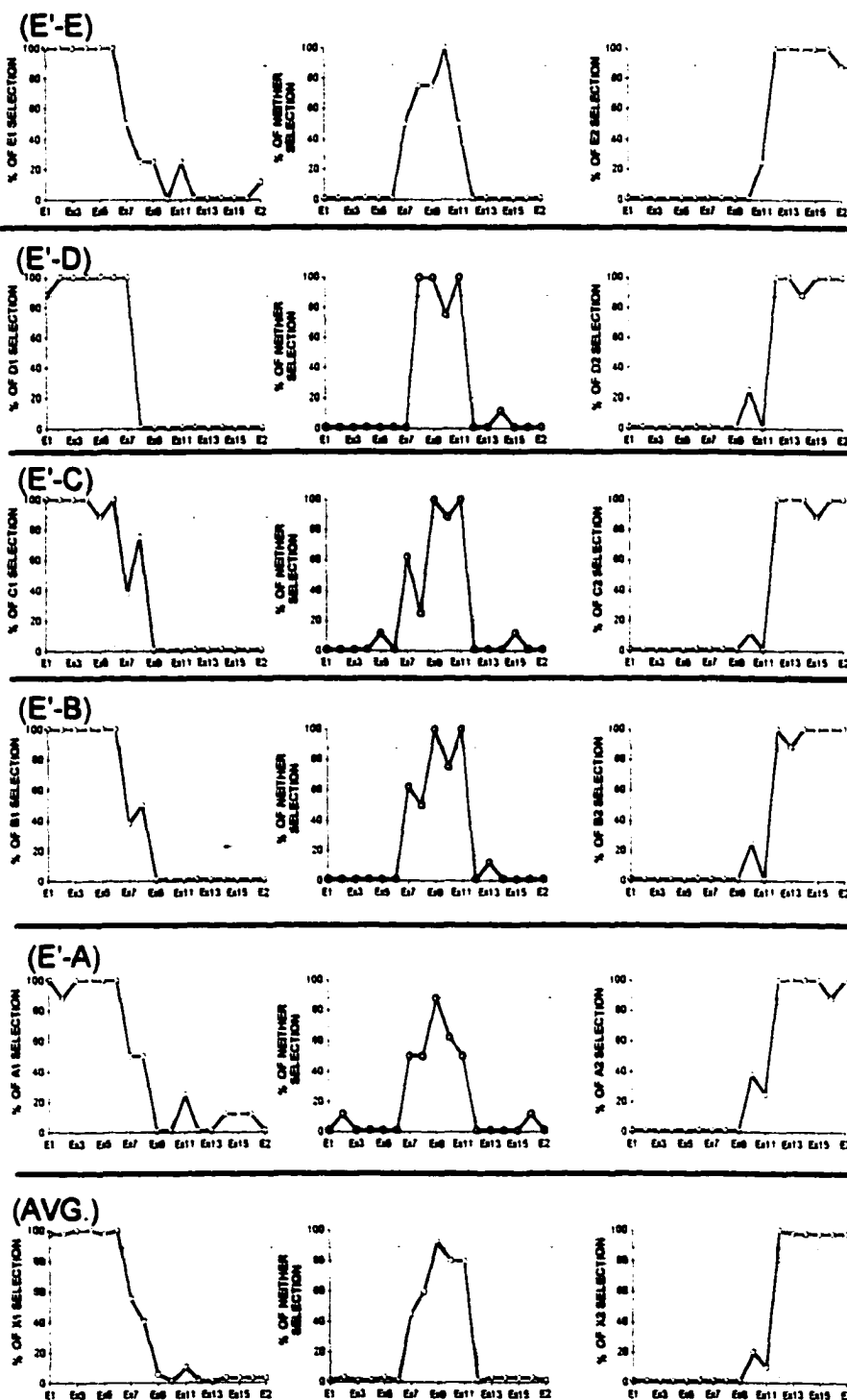
Subject - AB3

Appendix A - continued

Class 1

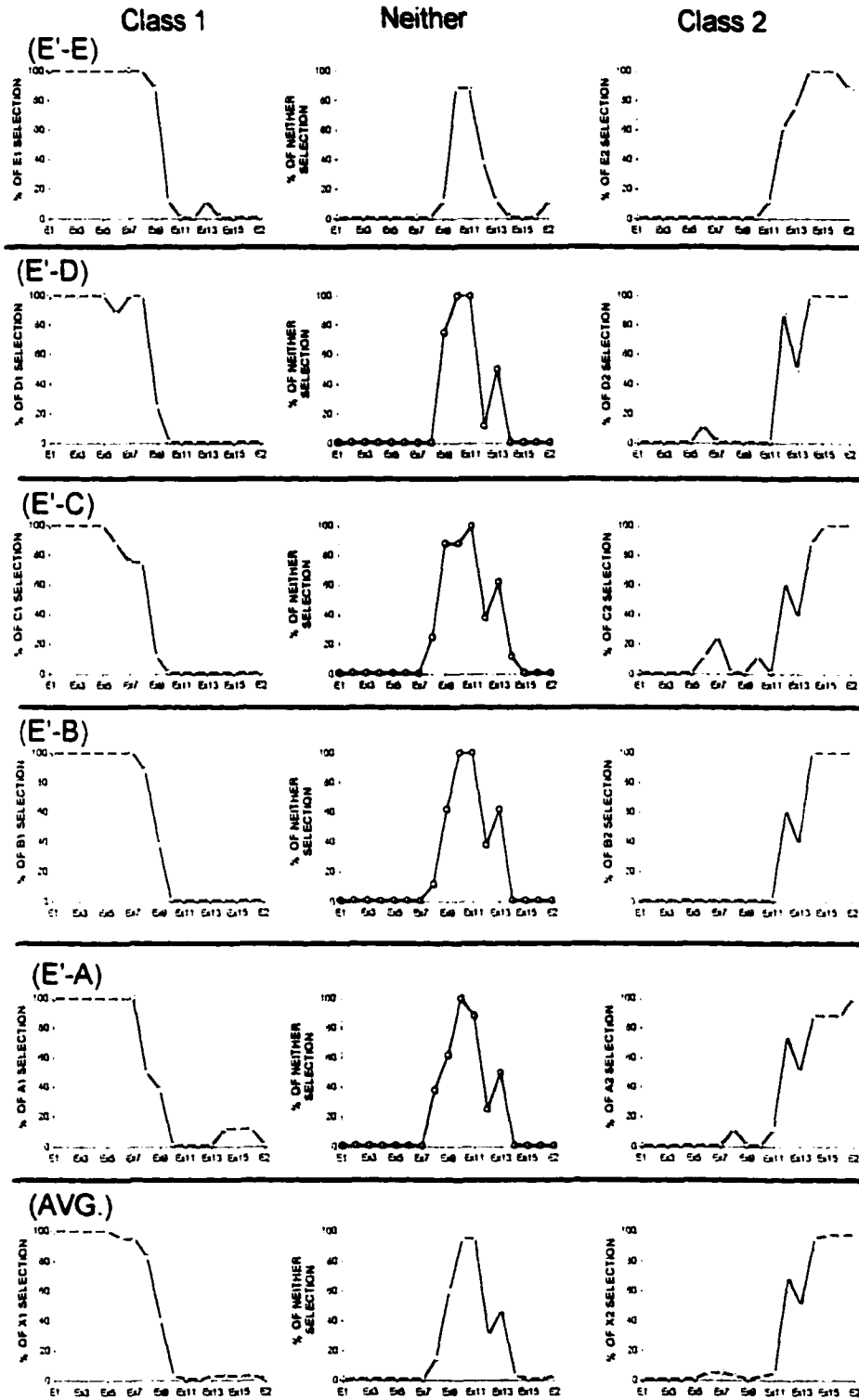
Neither

Class 2



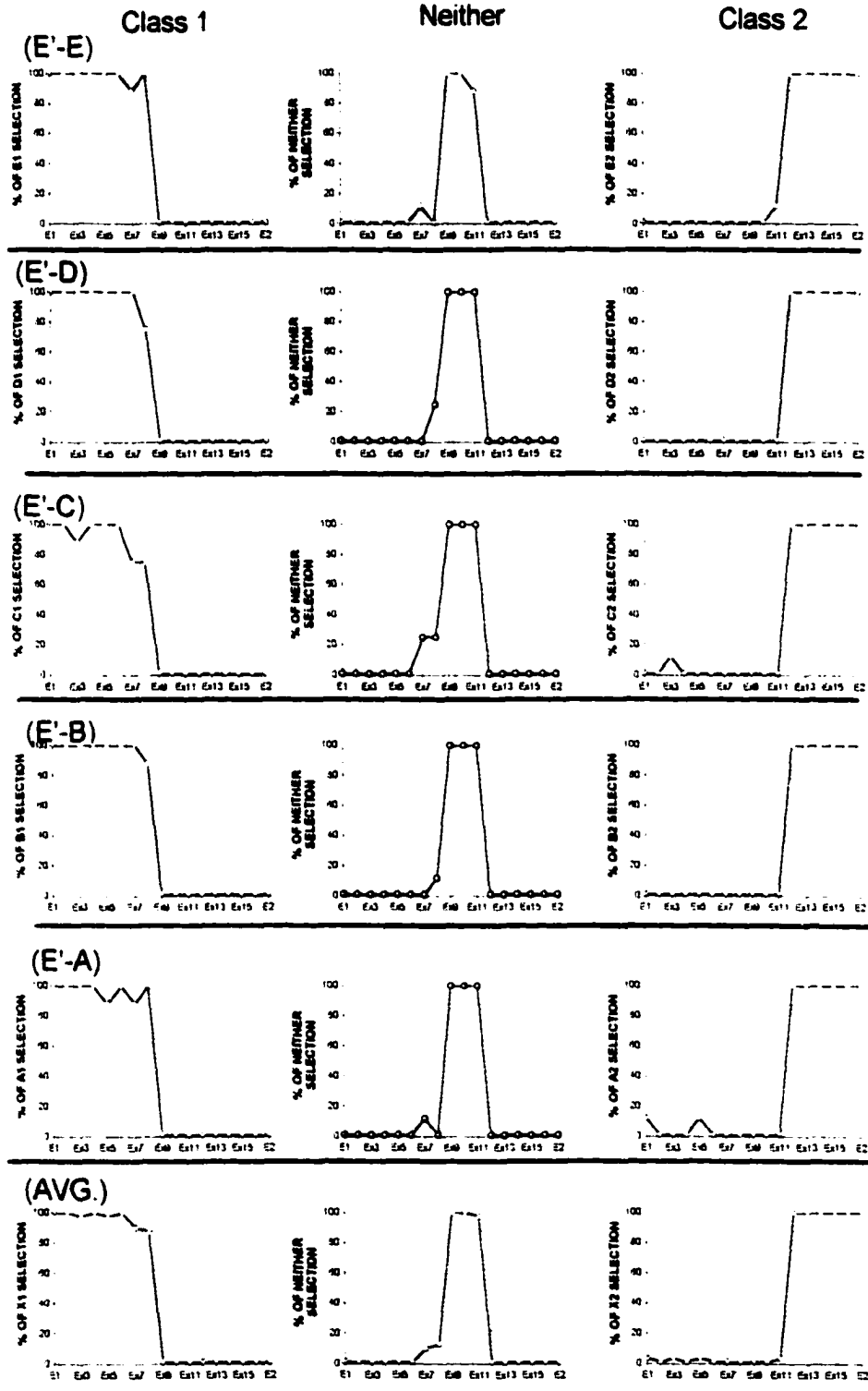
Subject - AE3

Appendix A - continued



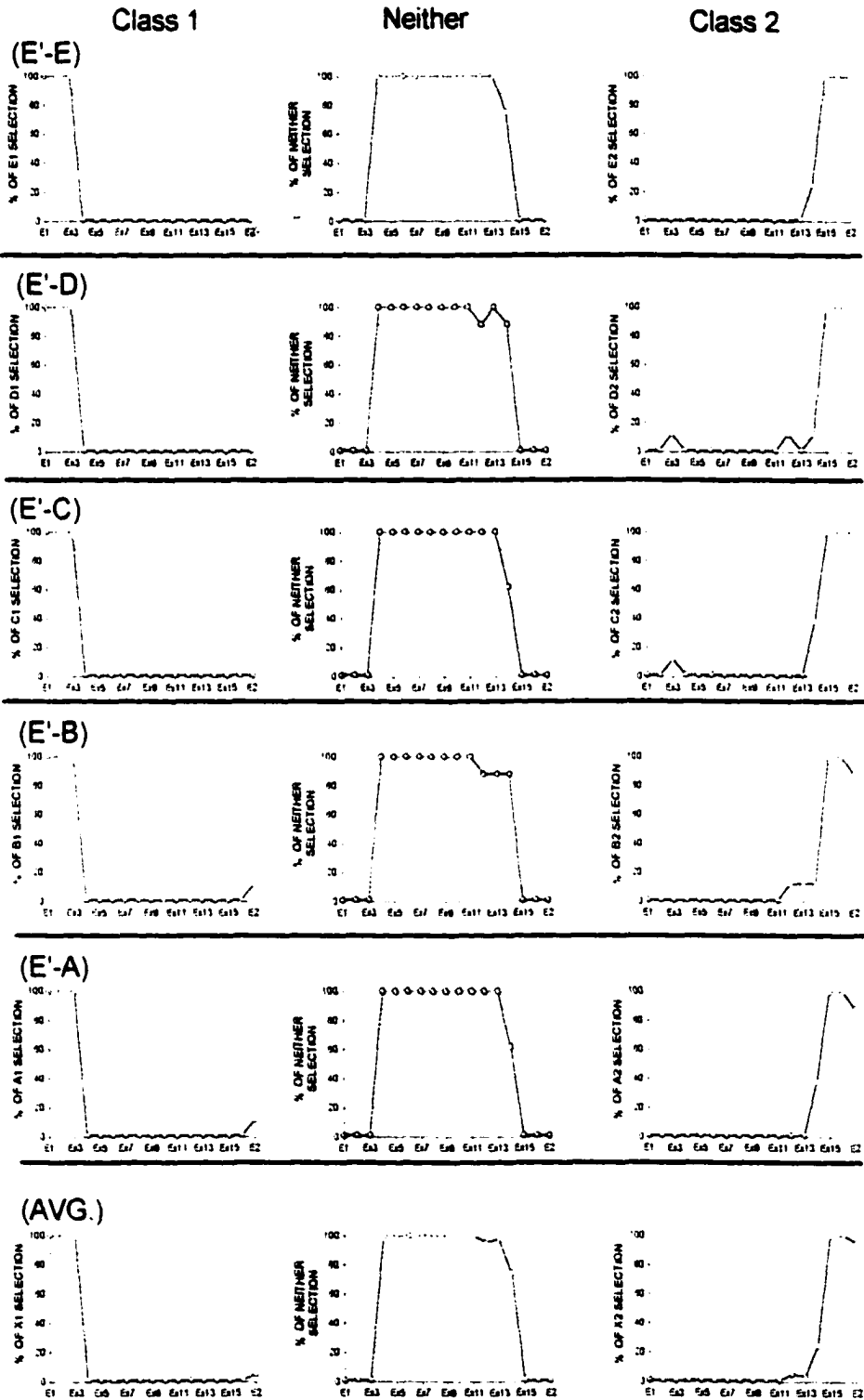
Subject - MM3

Appendix A - continued

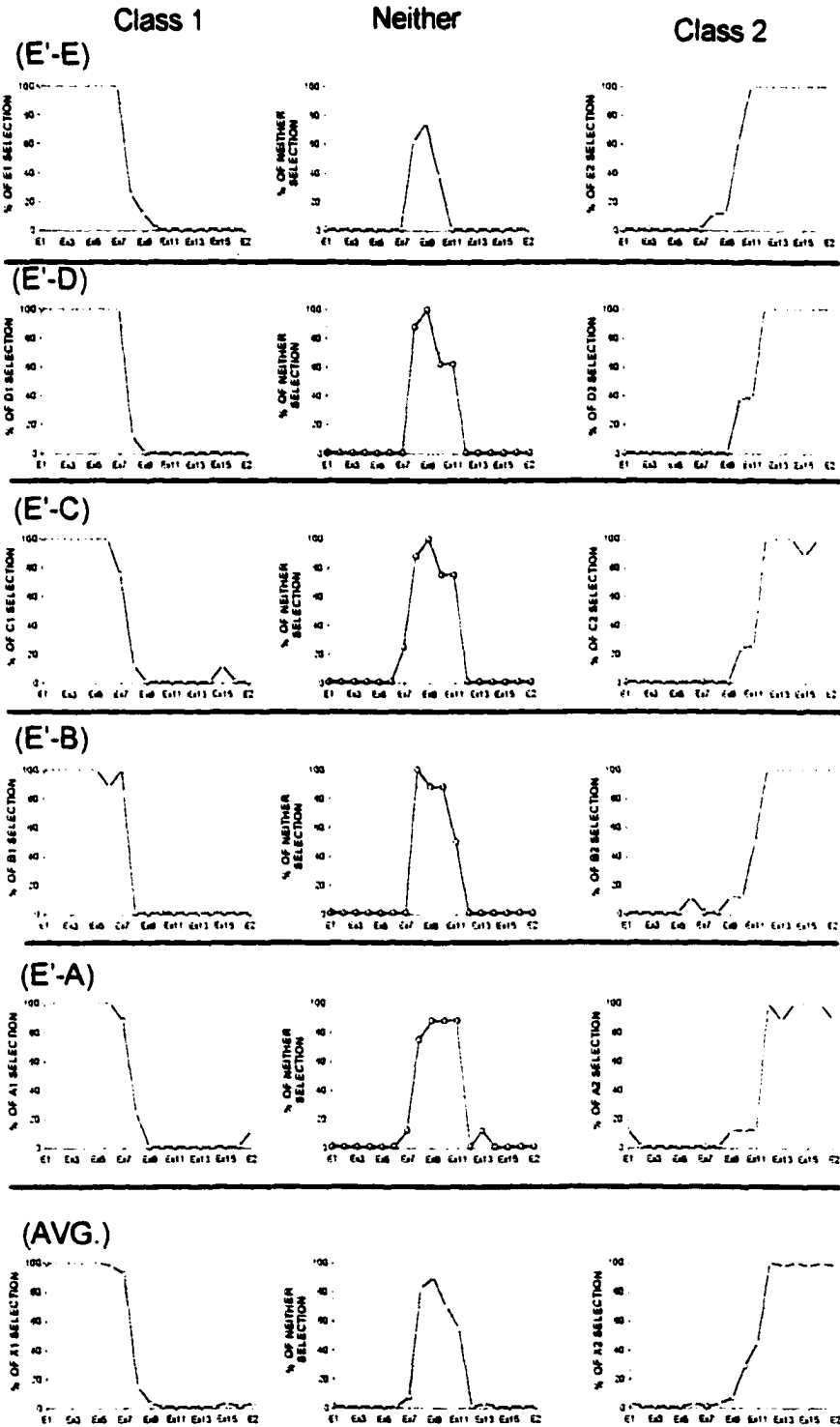


Subject - EV3

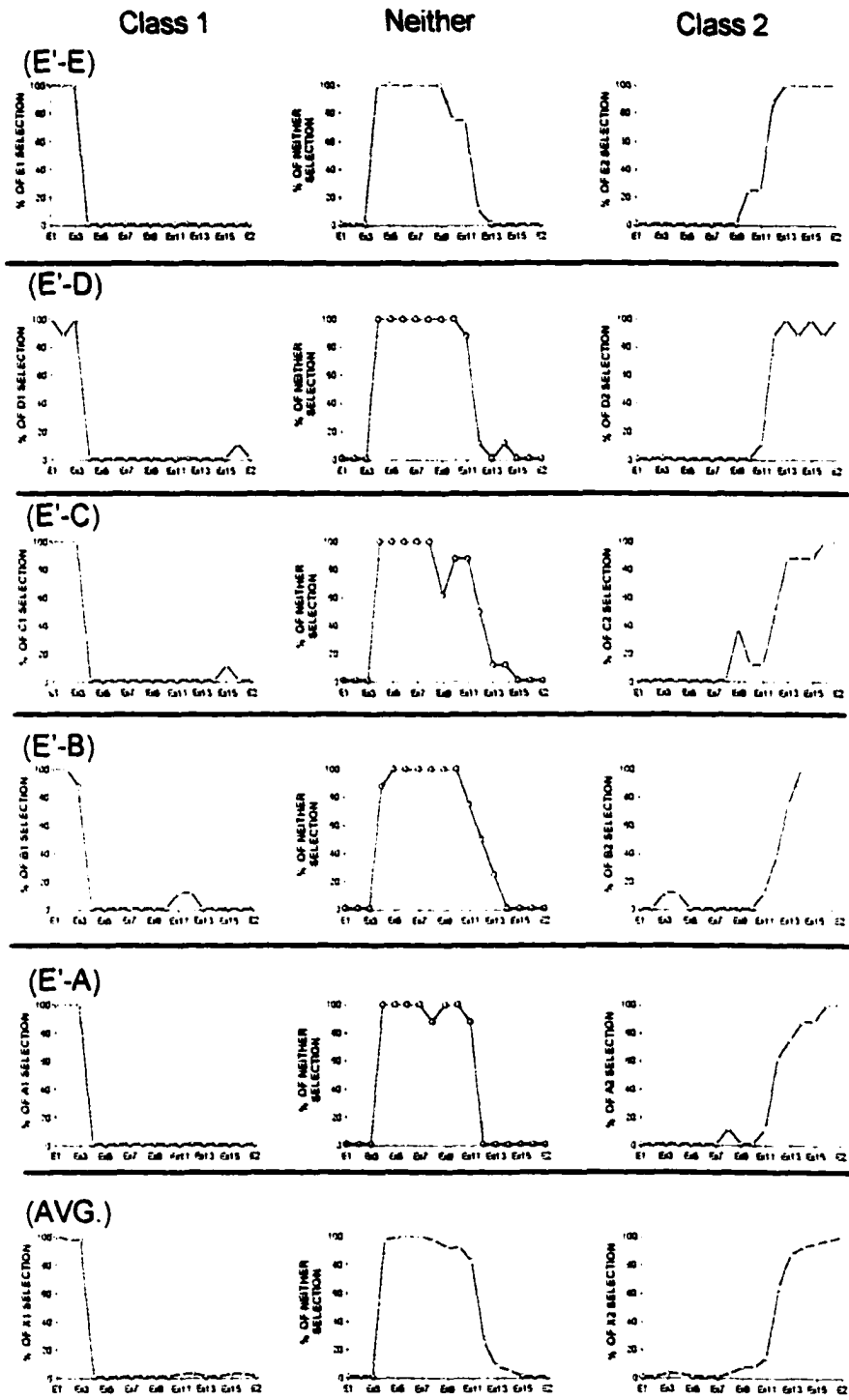
Appendix A - continued



Subject - SD3



Subject - AL3



Appendix B - Errors

Below is a list of all the untrained responses that occurred during the response transfer test for all subjects. Each untrained response is listed first, followed by the stimuli which occasioned the untrained response. All numbers in the response listing indicate the number of times the next letter was pressed consecutively. The responses in quotes, indicate the exact response sequence emitted. The parenthetical numbers after the stimuli indicate the number of times that the particular stimulus occasioned the specific response. If no parenthetical number is present, the response occurred once. During the response transfer test, all stimuli were presented 8 times each.

SUBJ.	ERROR	STIMULI
HC1	3J	EX7, EX9
	8J	EX16, C2
GD1	13J	EX7
EW1	9JE	EX11
	10J	EX13, EX15, E2, B2
	H5J	E1
	H9J	EX16
	J3N	EX8
DA2	N3J	EX7
	4N	EX9
	7JE7J	EX13
	7JE	EX16
	4J	EX2
	8J	EX13
	3JE	A1
MK2	6J	EX16
	N7J	A2
PM2	8J	D2
AH2	3JE	A1, D1, EX3 (2), EX9
	7J'	C2
	7JE	A2, C2, EX10(2), EX11, EX14(2), EX15,
	8J	B2
EY2	3JE	C1, EX6, EX9
	7JE	EX16
MT2	7JE	A2
	33JJJ	A1

Appendix B, continued

SUBJ.	ERROR	STIMULI
AE3	BLANK K5J 6J	EX10 EX4 EX2, EX5
AB3	6J 3J2N 4J 3NE 5JE 8J 4N	D1, EX2, EX3, EX7 EX11 D1 EX9 EX2 A2(2) EX11
MM3	6J 5JE J3N 4JP 8J	A1 D1 EX12 EX16 EX14
SD3	7J 4J 2JK NNN] 10J 8J	D2 EX10 EX5 EX10 E2 A1, EX15, EX16
EV3	4J 9J 2J 9J'E 3N'E 8J 9JE 3JE	EX8 EX16 EX6 EX3 EX13 EX10 E2

Appendix B, continued

SUBJ.	ERROR	STIMULI
AL3	7J	A1, C1, EX9(2), EX14(2), EX16, E2
	3NE	A1, B1, D1(2), EX4(3), EX8, E2
	10J	EX14
	5J	EX11, EX12
	8J	A1(2), EX7, EX12(2), EX13(3), EX14, EX15(2), EX16(2)
	8JE	EX12, E2
	3J	C1
	N N	EX7
	3JE	EX3, EX10, EX16, E2
	4N	EX7
	JUJ	EX3

Appendix C.

Performance in each discriminability block.

GROUP 1

SUBJECT	CONSEC. BLOCKS	STAGE 1	STAGE 2	STAGE 3	STAGE 4
GD1	1	25	92	100	100
	2	37	100	100	100
	3	83	100	100	100
	4	100	100	100	100
	5	100	100		
	6	100			
	7	100			
HC1	1	75	83	100	100
	2	75	100	100	100
	3	83	92	100	100
	4	75	100	100	100
	5	100	100		
	6	92	100		
	7	100			
	8	100			
	9	92			
	10	100			
EW1	1	75	83	100	100
	2	92	100	100	100
	3	100	100	100	100
	4	100	100	100	100
	5	100	100		
	6	100			

Appendix C, continued

GROUP 2

SUBJECT	CONSEC. BLOCKS	STAGE 1	STAGE 2	STAGE 3	STAGE 4
DA2	1	50	92	75	83
	2	50	100	83	100
	3	42	100	100	100
	4	58	100	100	100
	5	75	100	100	100
	6	75		100	
	7	67			
	8	92			
	9	92			
	10	100			
	11	92			
	12	100			
	13	100			
	14	100			
MK2	1	75	100	100	100
	2	100	100	100	100
	3	92	100	100	100
	4	100	92	100	100
	5	100	100		
	6	100			

Transfer of Responding 73

PM2	1	50	83	100	100
	2	50	92	100	100
	3	75	100	100	100
	4	100	100	100	100
	5	100	100		
	6	100	100		
	7	100			

MT2	1	67	87	100	100
	2	100	100	100	100
	3	100	100	100	100
	4	100	100	100	100
	5	100	100		

AH2	1	83	100	100	100
	2	100	100	100	92
	3	100	100	100	100
	4	100	100	100	100
	5	100			100

Transfer of Responding 74

EY2	1	33	75	83	100
	2	25	83	100	100
	3	33	100	100	100
	4	33	100	100	100
	5	25	100	100	
	6	33	100		
	7	50			
	8	33			
	9	42			
	10	42			
	11	50			
	12	75			
	13	92			
	14	100			
	15	100			
	16	100			
	17	100			

Appendix C, continued

GROUP 3

SUBJECT	CONSEC. BLOCKS	STAGE 1	STAGE 2	STAGE 3	STAGE 4
AE3	1	50	83	92	100
	2	42	100	100	100
	3	50	100	100	100
	4	83	100	100	100
	5	75	100	100	
	6	83			
	7	92			
	8	92			
	9	100			
	10	100			
	11	100			
	12	100			
AB3	1	58	92	75	100
	2	75	100	100	100
	3	83	100	100	100
	4	100	100	100	100
	5	100	100	100	
	6	100			
	7	100			
MM3	1	75	83	100	100
	2	100	100	100	100
	3	100	100	100	100
	4	100	100	100	100
	5	100	100		

Transfer of Responding 76

SD3	1	42	75	92	83
	2	50	100	100	100
	3	42	92	100	100
	4	75	100	100	100
	5	75	100	100	100
	6	83	100		
	7	75			
	8	83			
	9	100			
	10	92			
	11	100			
	12	100			
	13	100			

EV3	1	67	83	100	92
	2	75	100	100	100
	3	75	100	100	100
	4	92	100	100	100
	5	100	100		100
	6	92			
	7	100			
	8	100			
	9	100			

AL3	1	67	83	83	100
	2	100	100	100	100
	3	83	92	100	100
	4	92	92	100	100
	5	100	100	100	
	6	92	100		
	7	83	100		
	8	100			
	9	100			

Table 1.
List of relations presented during each training and testing block during both equivalence class formation and the establishment of generalized equivalence classes.

GROUP 1 & 2		GROUP 3	
BLOCK NAME	A1->B1->C1->D1->E1 A2->B2->C2->D2->E2	BLOCK NAME	A1->B1<-C1->D1<-E1 A2->B2<-C2->D2<-E2
AB-TRAIN	A1-B1, A2-B2	AB-TRAIN	A1-B1, A2-B2
BA-SYM	B1-A1, B2-A2, A1-B1, A2-B2	BA-SYM	B1-A1, B2-A2, A1-B1, A2-B2
BC-TRAIN	A1-B1, A2-B2, B1-C1, B2-C2	CB-TRAIN	A1-B1, A2-B2, C1-B1, C2-B2
CB-SYM	C1-B1, C2-B2, B1-C1, B2-C2	BC-SYM	B1-C1, B2-C2, C1-B1, C2-B2
BACB-SYM	B1-A1, B2-A2, C1-B1, C2-B2 A1-B1, A2-B2, B1-C1, B2-C2	BABC-SYM	B1-A1, B2-A2, B1-C1, B2-C2 A1-B1, A2-B2, C1-B1, C2-B2
AC-TTY	A1-C1, A2-C2, A1-B1, A2-B2 B1-C1, B2-C2	AC-EQV	A1-C1, A2-C2, A1-B1, A2-B2 C1-B1, C2-B2
CA-EQV	C1-A1, C2-A2, A1-C1, A2-C2 A1-B1, A2-B2, B1-C1, B2-C2	CA-EQV	C1-A1, C2-A2, A1-C1, A2-C2 A1-B1, A2-B2, C1-B1, C2-B2
3-MIX	A1-B1, A2-B2, B1-C1, B2-C2 B1-A1, B2-A2, C1-B1, C2-B2 C1-A1, C2-A2, A1-C1, A2-C2	3-MIX	A1-B1, A2-B2, C1-B1, C2-B2 B1-A1, B2-A2, B1-C1, B2-C2 A1-C1, A2-C2, C1-A1, C2-A2
CD-TRAIN	C1-D1, C2-D2 A1-B1, A2-B2, B1-C1, B2-C2	CD-TRAIN	C1-D1, C2-D2 A1-B1, A2-B2, C1-B1, C2-B2
4-MIX	A1-B1, A2-B2, B1-C1, B2-C2 C1-D1, C2-D2, B1-A1, B2-A2 C1-B1, C2-B2, D1-C1, D2-C2 C1-A1, C2-A2, A1-C1, A2-C2 A1-D1, A2-D2, D1-A1, D2-A2 B1-D1, B2-D2, D1-B1, D2-B2	4-MIX	A1-B1, A2-B2, C1-B1, C2-B2 C1-D1, C2-D2, B1-A1, B2-A2 B1-C1, B2-C2, D1-C1, D2-C2 A1-C1, A2-C2, C1-A1, C2-A2 A1-D1, A2-D2, D1-A1, D2-A2 B1-D1, B2-D2, D1-B1, D2-B2
DE-TRAIN	D1-E1, D2-E2	ED-TRAIN	E1-D1, E2-D2
5-MIX	A1-B1, A2-B2, B1-A1, B2-A2 C1-B1, C2-B2, B1-C1, B2-C2 D1-C1, D2-C2, C1-D1, C2-D2 D1-E1, D2-E2, E1-D1, E2-D2 A1-C1, A2-C2, C1-A1, C2-A2 B1-D1, B2-D2, D1-B1, D2-B2 C1-E1, C2-E2, E1-C1, E2-C2 A1-D1, A2-D2, D1-A1, D2-A2 B1-E1, B2-E2, E1-B1, E2-B2 A1-E1, A2-E2, E1-A1, E2-A2	5-MIX	A1-B1, A2-B2, B1-A1, B2-A2 B1-C1, B2-C2, C1-B1, C2-B2 D1-C1, D2-C2, C1-D1, C2-D2 E1-D1, E2-D2, D1-E1, D2-E2 A1-C1, A2-C2, C1-A1, C2-A2 B1-D1, B2-D2, D1-B1, D2-B2 C1-E1, C2-E2, E1-C1, E2-C2 A1-D1, A2-D2, D1-A1, D2-A2 B1-E1, B2-E2, E1-B1, E2-B2 A1-E1, A2-E2, E1-A1, E2-A2
GEC-TST	E1'-A1, E2'-A2, E1'-B1, E2'-B2 E1'-C1, E2'-C2, E1'-D1, E2'-D2 E1'-E1, E2'-E2	GEC-TST	E1'-A1, E2'-A2, E1'-B1, E2'-B2 E1'-C1, E2'-C2, E1'-D1, E2'-D2 E1'-E1, E2'-E2

Table 2.

Number of blocks to learn each baseline relation and pass each emergent relations test. The first column indicates the trial block name. The specific trial types within those blocks are listed in Table 1. The first four rows list the training blocks and are followed by eight rows that list the eight emergent relations test blocks. The second column shows the minimum blocks for each specific block type. The remaining columns indicate the number of blocks each subject needed to complete a trial block type.

Block Name	Min. # trials	Group 1			Group 2					
		HCl	GD1	EW1	DA2	MX2	PM2	MT2	AH2	EY2
AB-TRAIN	4	15	5	4	5	6	5	6	6	6
BC-TRAIN	4	5	4	6	5	3	7	5	5	5
CD-TRAIN	4	6	7	6	5	5	9	4	6	10
DE-TRAIN	4	5	5	11	5	5	4	5	5	5
BA-SYM	1	1	1	1	1	1	1	1	1	1
CB-SYM	1	1	1	1	1	1	1	1	1	1
SACB-SYM	1	1	1	1	1	1	1	1	1	1
AC-TTY	1	1	2	5	2	3	1	1	1	6
CA-EQV	1	1	1	1	1	1	2	1	1	2
3-MIX	1	1	2	4	1	2	1	1	1	1
4-MIX	1	3	3	2	1	4	2	1	1	1
5-MIX	1	1	1	1	1	3	1	1	1	3
DISC	4	6	6	7	5	5	5	5	3	6

Group 3

Block Name	Min. # Trials	Group 3					
		AE3	AB3	MM3	SD3	EV3	AL3
AB-TRAIN	4	30	5	6	28	5	5
CB-TRAIN	4	5	3	6	13	5	5
CD-TRAIN	4	24	25	5	16	5	5
ED-TRAIN	4	5	6	5	10	5	16
BA-SYM	1	4	1	1	1	1	1
BC-SYM	1	1	1	1	1	3	1
BABC-SYM	1	1	1	1	1	1	2
AC-EQV	1	1	1	1	1	1	1
CA-EQV	1	2	2	1	1	2	1
3-MIX	1	1	1	2	1	1	1
4-MIX	1	1	1	3	1	4	1
5-MIX	1	1	1	1	1	2	4
DISC	4	8	12	6	16	6	12

Table 3.
 Number of blocks to pass each stage of the assessment of discriminability. The minimum number of blocks to pass any stage was 4. The numerals in parentheses indicate the number of blocks that preceded the first block that occasioned at least 75% accuracy.

GROUP	Subj.	Stage 1	Stage 2	Stage 3	Stage 4
1	HC1	10	6	4	4
	GD1	7 (2)	4	4	4
	EW1	6	4	4	4
2	EYC	17 (11)	6	5	4
	DA2	14 (4)	6	6	3
	PM2	7 (2)	6	4	4
	MM2	6	6	4	4
	MT2	5 (1)	6	4	4
	AH2	5	4	4	5
3	SD3	13 (3)	6	5	5
	AE3	12 (3)	6	6	4
	AB3	7 (1)	6	6	4
	EV3	9 (1)	6	4	5
	AL3	9 (1)	7	4	4
	MM3	5	5	4	4

Figure 1. The members of both basal equivalence classes. Stimulus position within a class is indicated by the letter (A, B, C, D, or E) Class membership is represented by the number (1 or 2).

Figure 1.

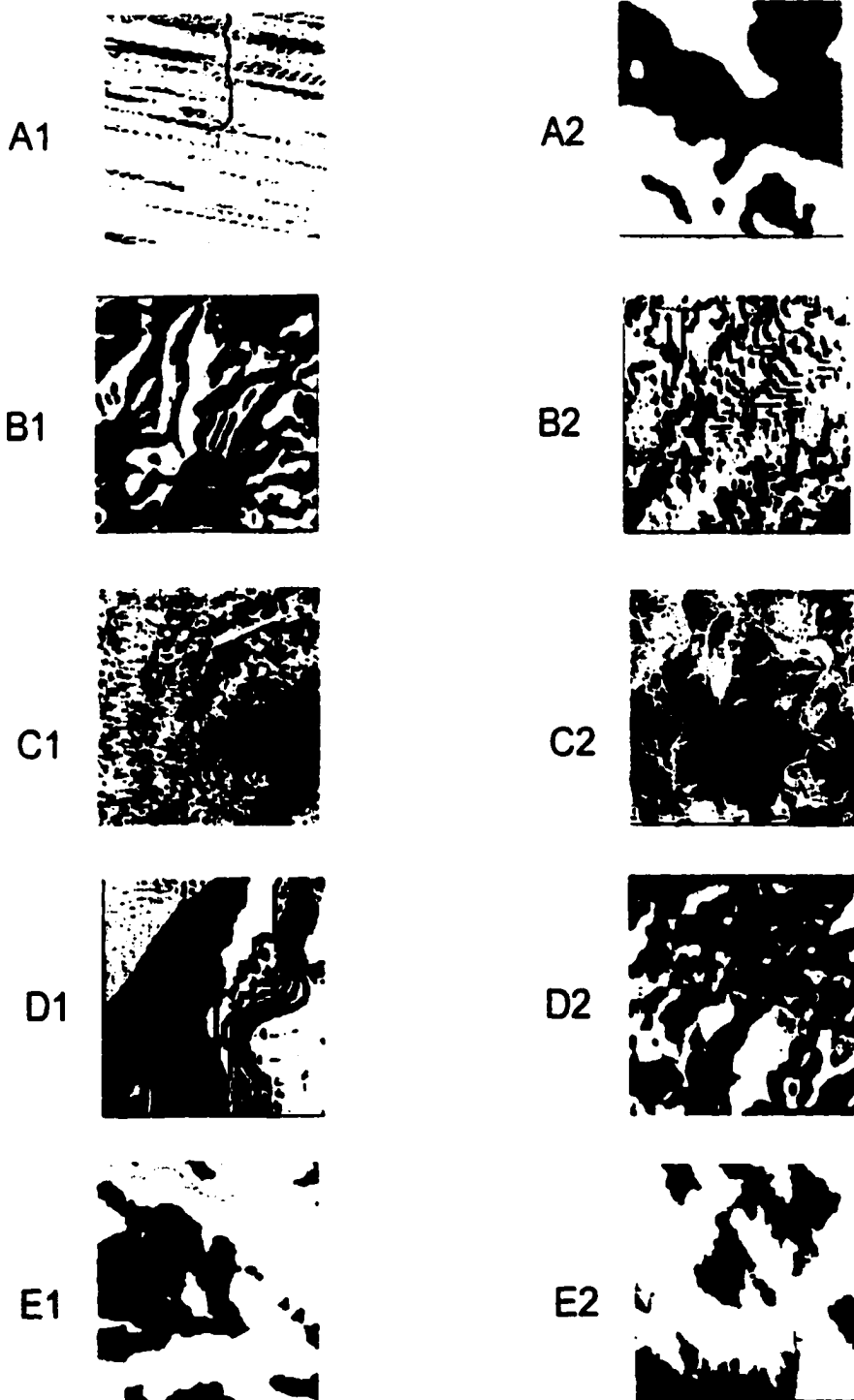


Figure 2. The seventeen variants of the E stimuli. The two anchor stimuli, E1 and E2, are represented with the values of Ex-1 and Ex-17, respectively.

Figure 2.

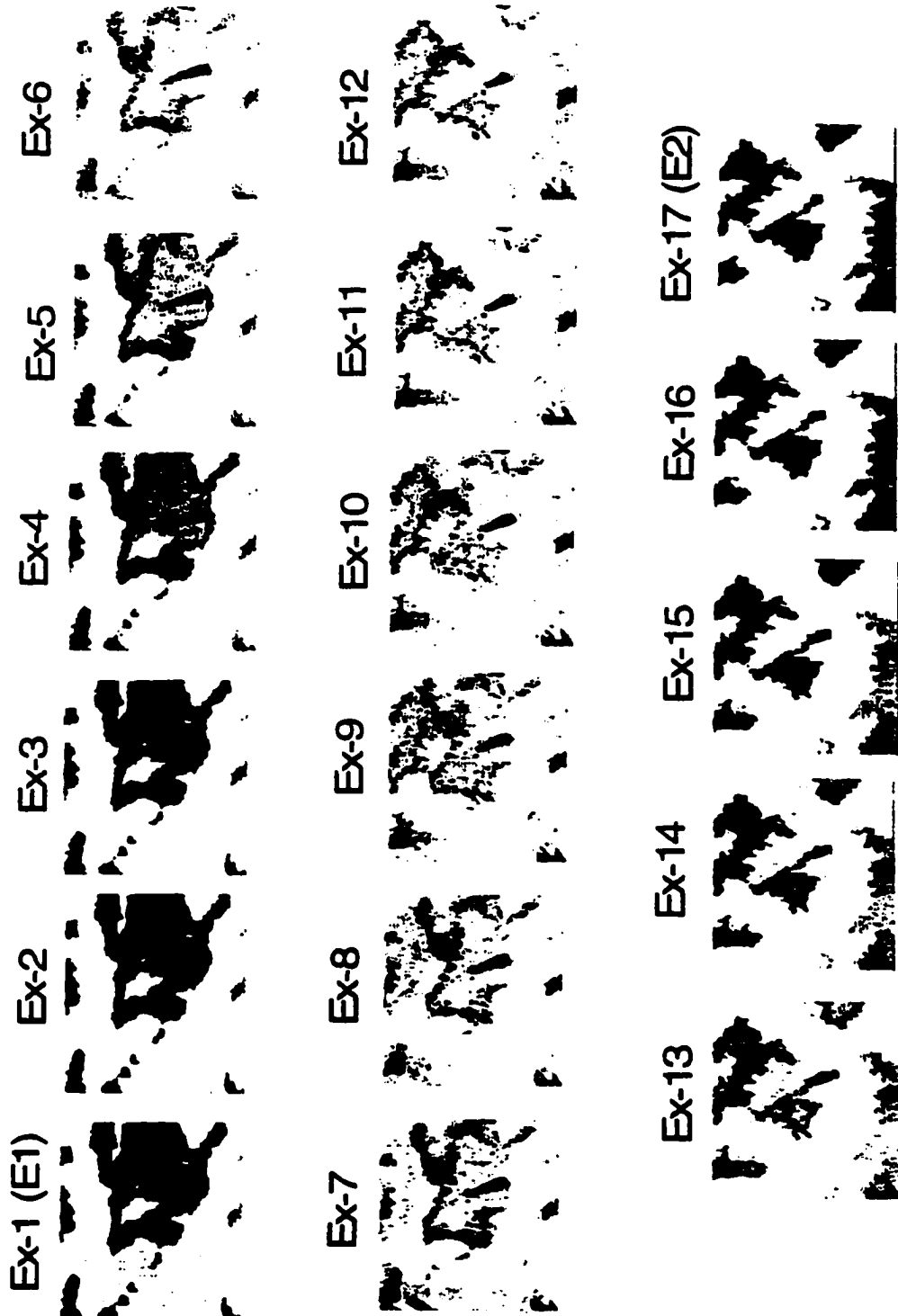


Figure 3. Five charts that show class structure, stimuli to which responses were trained, and the length of each response string. The arrows between equivalence class members indicate the direction of conditional discrimination training. The numbers linked to generalized equivalence class members indicate the number of J key presses reinforced in the presence of the specific stimulus.

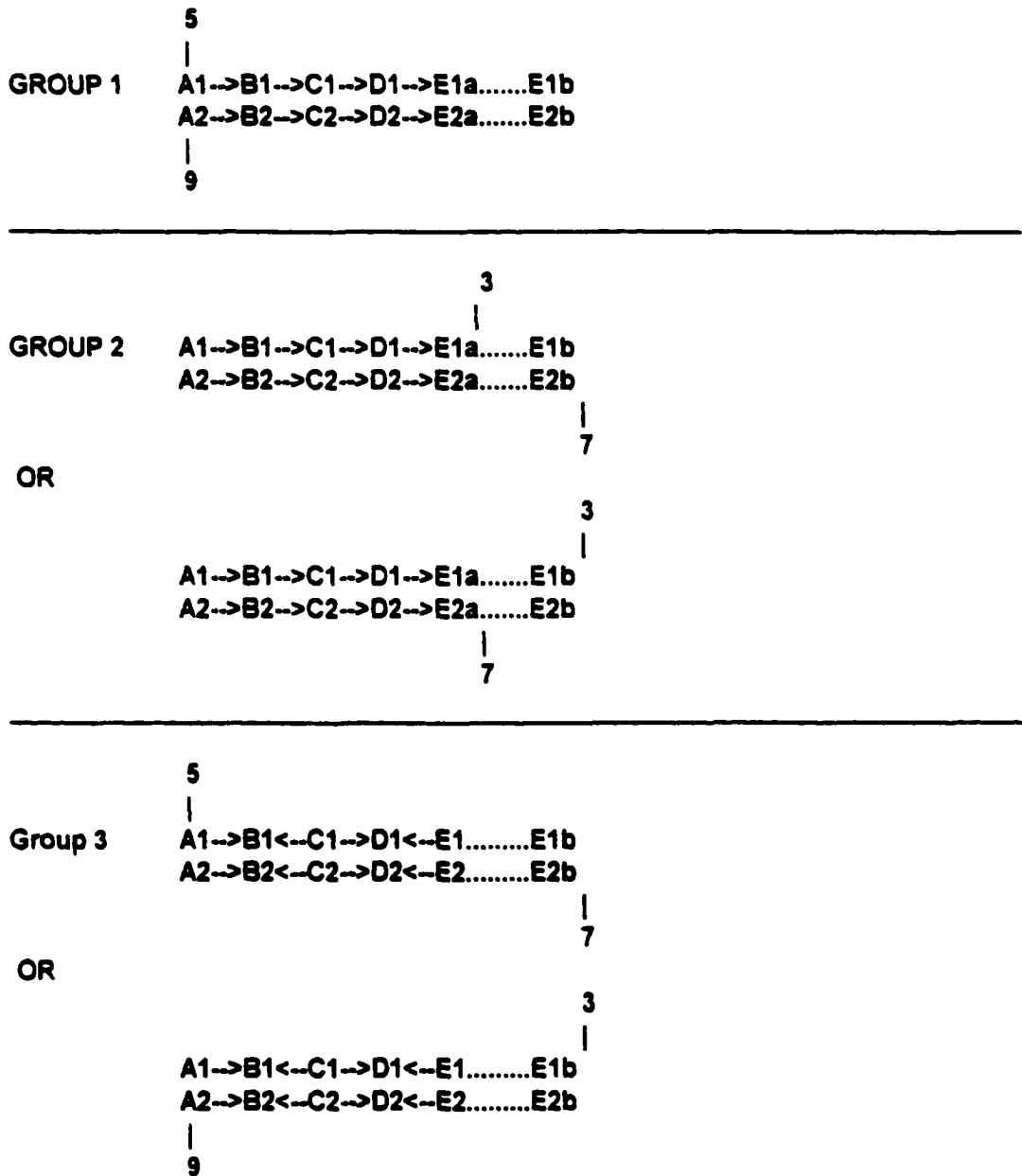


Figure 4. The results of the primary generalization tests for subjects in Group 1. Each row shows the results for one subject, and is labeled with the subjects' name to the left. Each graph shows the percentage of trials in which the subject selected a particular comparison plotted as a function of the stimulus values presented as samples. The horizontal dotted line shows the criterion level (88%) for perceptual class-consistent comparison selection. The vertical dotted lines indicate the boundaries of the perceptual classes as measured during the primary generalization test. The left column of graphs shows the results for the selection of the E1 comparison, the middle column of graphs shows the results for the selection of the neither comparison, and the right column of graphs shows the results for the selection of the E2 comparison.

Figure 4.

PRIMARY GENERALIZATION TEST
GROUP 1

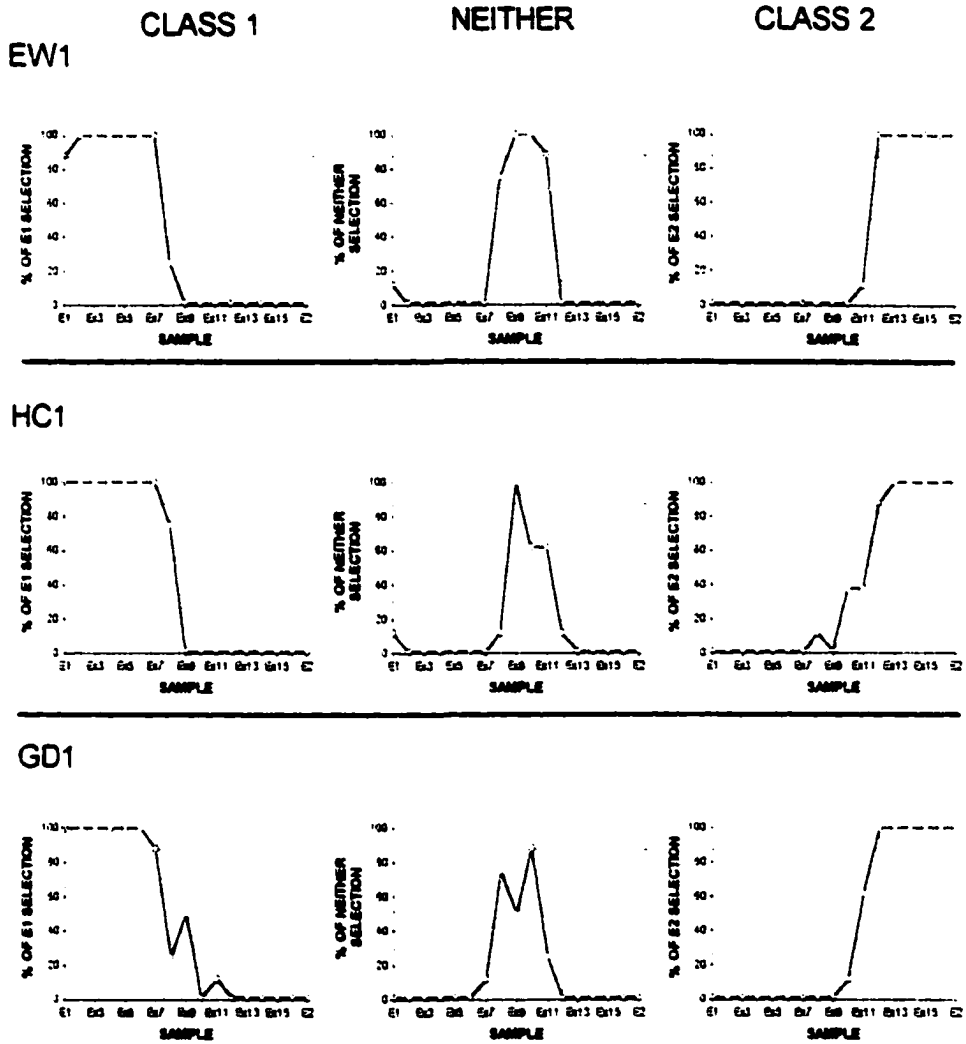


Figure 5. The results of the primary generalization tests for subjects in Group 2. The graphs are structured the same as those in Figure 4.

PRIMARY GENERALIZATION TEST
GROUP 2

Figure 5.

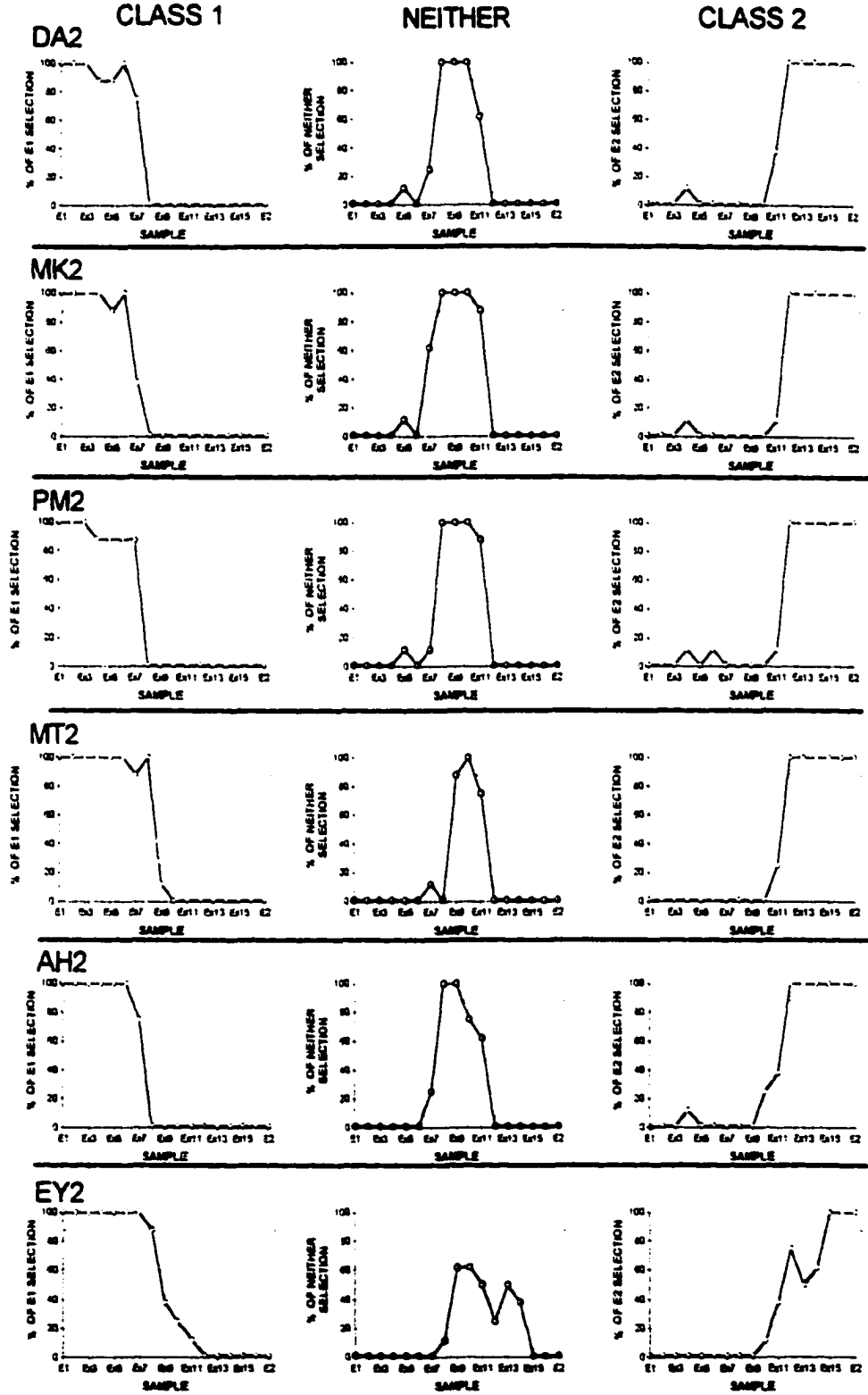


Figure 6. The results of the primary generalization tests for subjects in Group 3. The graphs are structured the same as those in Figure 4.

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PRIMARY GENERALIZATION TEST
GROUP 3

Figure 6

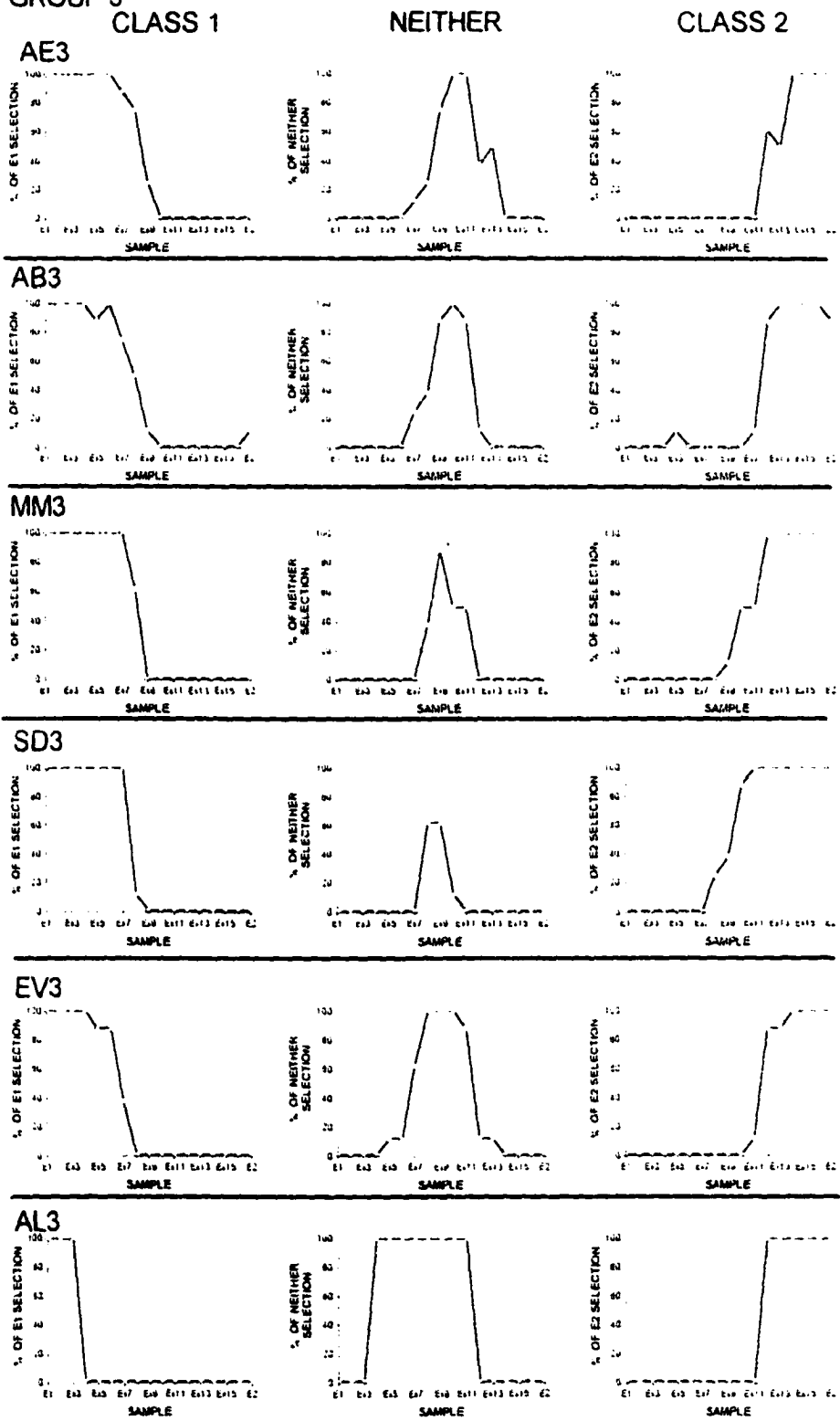


Figure 7. The relative frequency of the width of the perceptual classes for all subjects. Each bar indicates the relative frequency of the width of perceptual classes occasioned across all subjects. The width of a perceptual class was measured by the number of variants which occasioned the selection of either E1 or E2 at above criterion level.

RELATIVE FREQUENCY OF PERCEPTUAL CLASS WIDTHS FOR ALL SUBJECTS

WIDTH OF PERCEPTUAL CLASSES (RANGE)

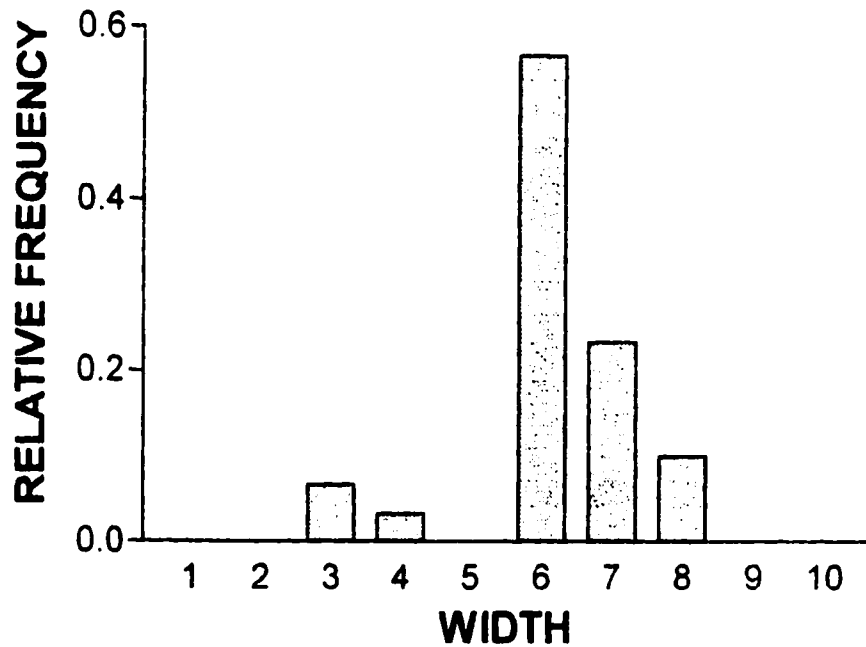


Figure 8. The results for subjects EW1 of the individual generalization tests of emergent relations. The parenthetical label for each row indicates the specific relation presented in that row of graphs. Each graph plots the percentage of trials in which the subject selected a particular comparison as a function of the stimulus values presented as samples. The horizontal dotted line shows the criterion level (88%) for perceptual class-consistent comparison selection. The vertical dotted lines indicate the boundaries of the perceptual classes as measured during the primary generalization test. The left column of graphs shows the results for the comparisons from Class 1, the middle column of graphs shows the results for the selection of the neither comparison, and the right column of graphs shows the results for the comparisons from Class 2.

Figure 8.

GENERALIZED EMERGENT RELATIONS

Subject - EW1

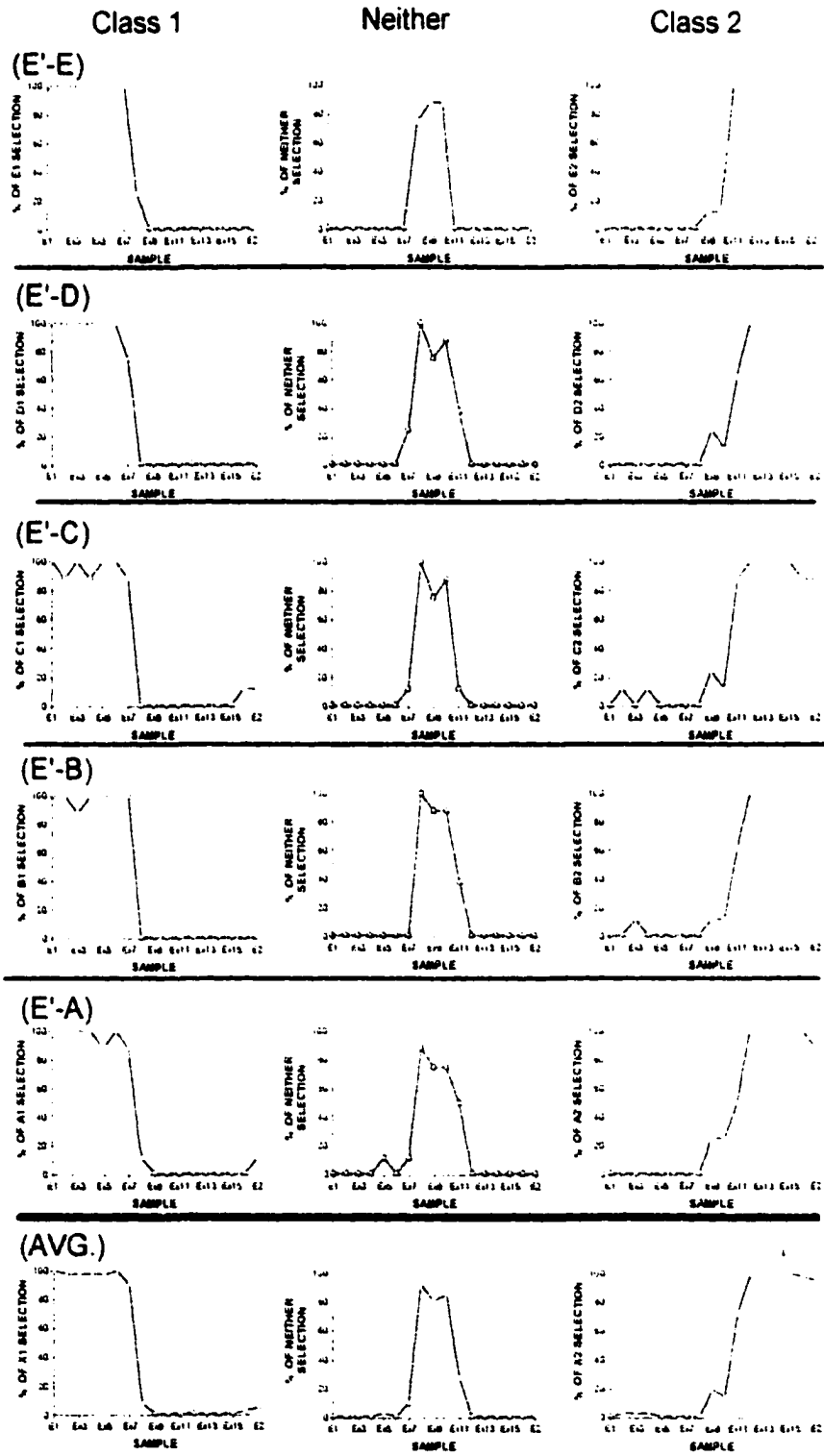


Figure 9. The average of the generalization tests of emergent relations for subjects in Group 1. Each row of graphs shows the results for a particular subject. The graphs are structured the same as those in Figure 8.

Figure 9.

AVG. OF GENERALIZATION TESTS
OF EMERGENT RELATIONS - GROUP 1

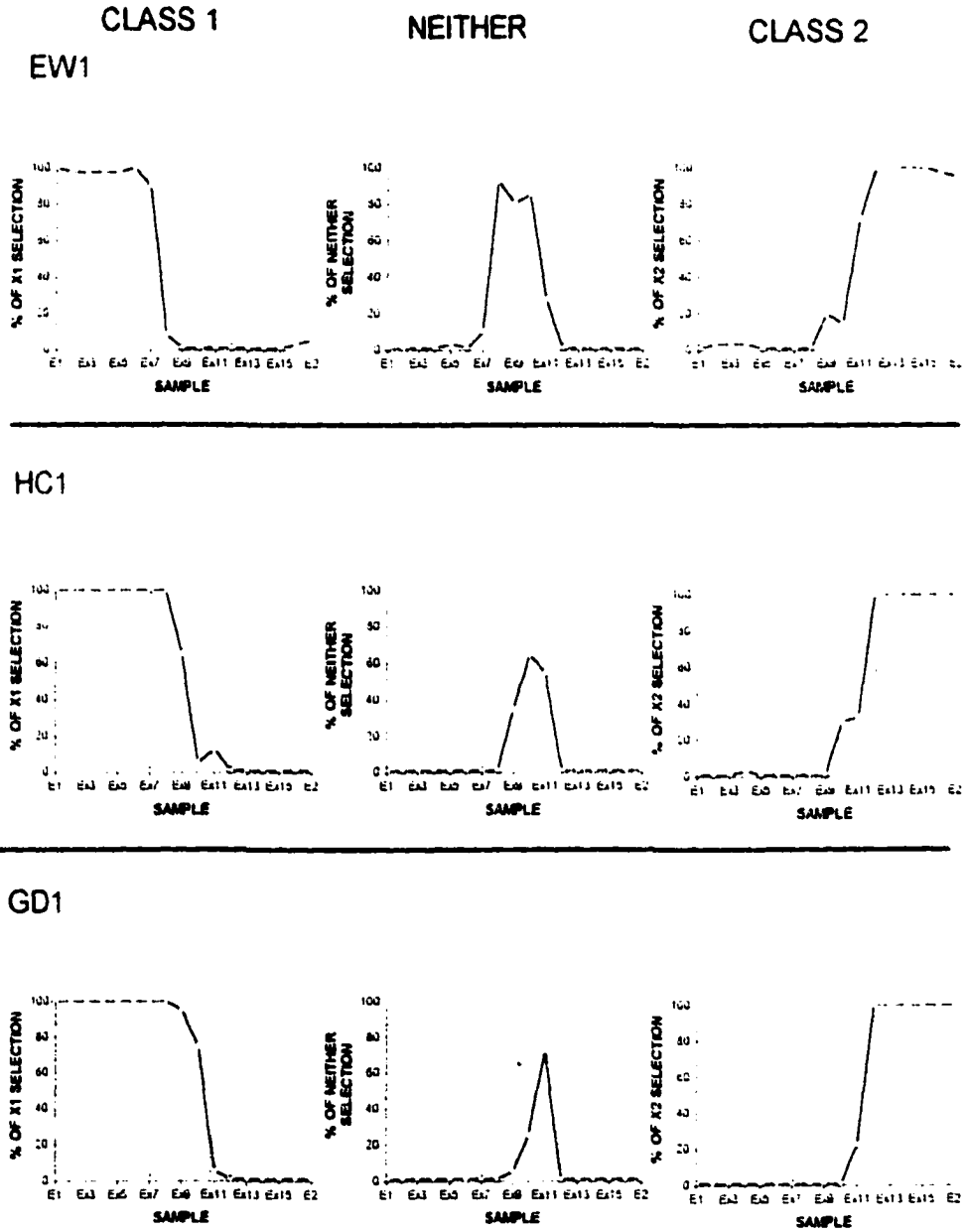


Figure 10. The average of the generalization tests of emergent relations for subjects in Group 2. Each row of graphs shows the results for a particular subject. The graphs are structured the same as those in Figure 8.

AVG. OF GENERALIZATION TESTS
OF EMERGENT RELATIONS - GROUP 2

Figure 10.

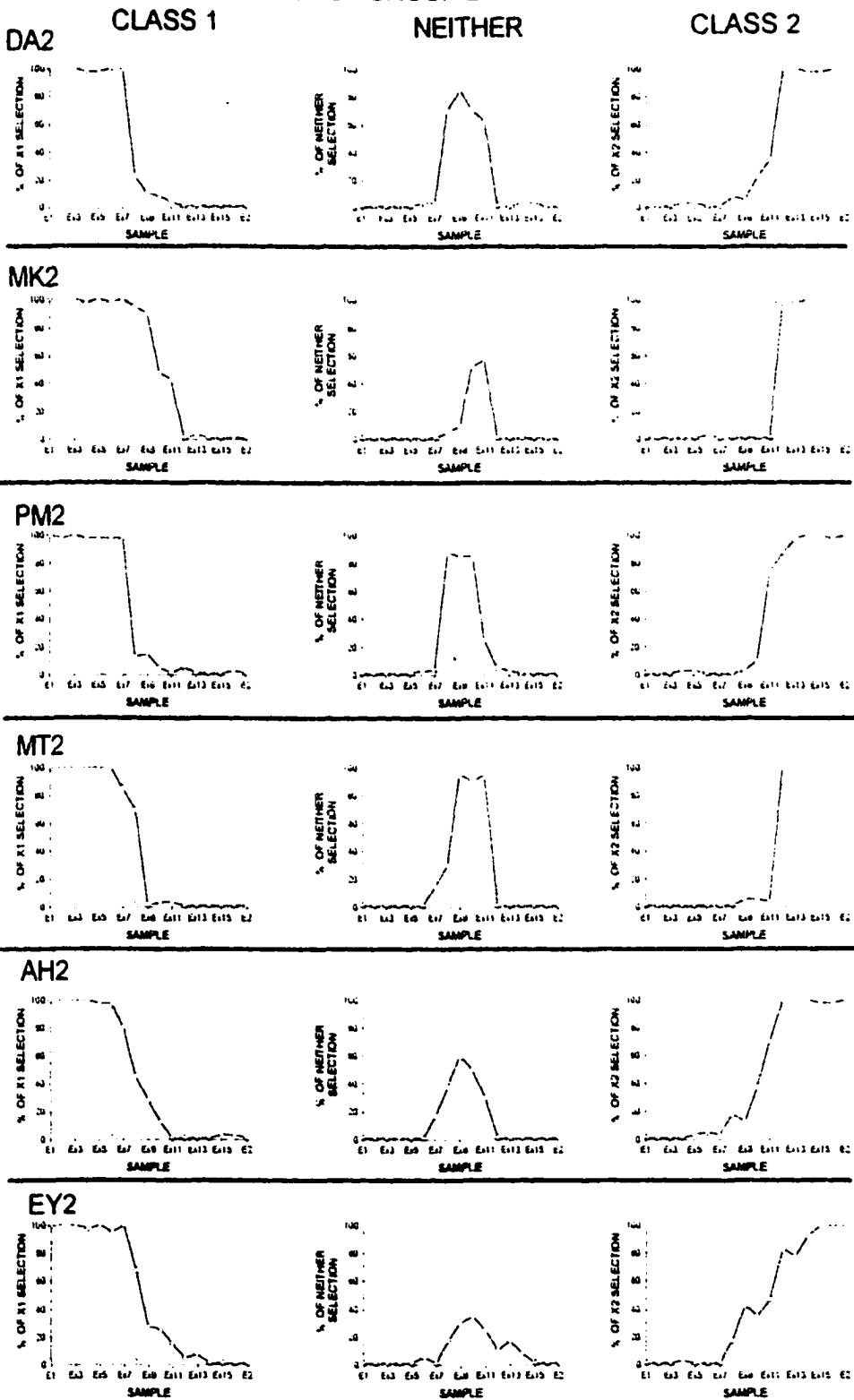


Figure 11. The average of the generalization tests of emergent relations for subjects in Group 3. Each row of graphs shows the results for a particular subject. The graphs are structured the same as those in Figure 8.

AVG. OF GENERALIZATION TESTS
OF EMERGENT RELATIONS - GROUP 3

Figure 11.

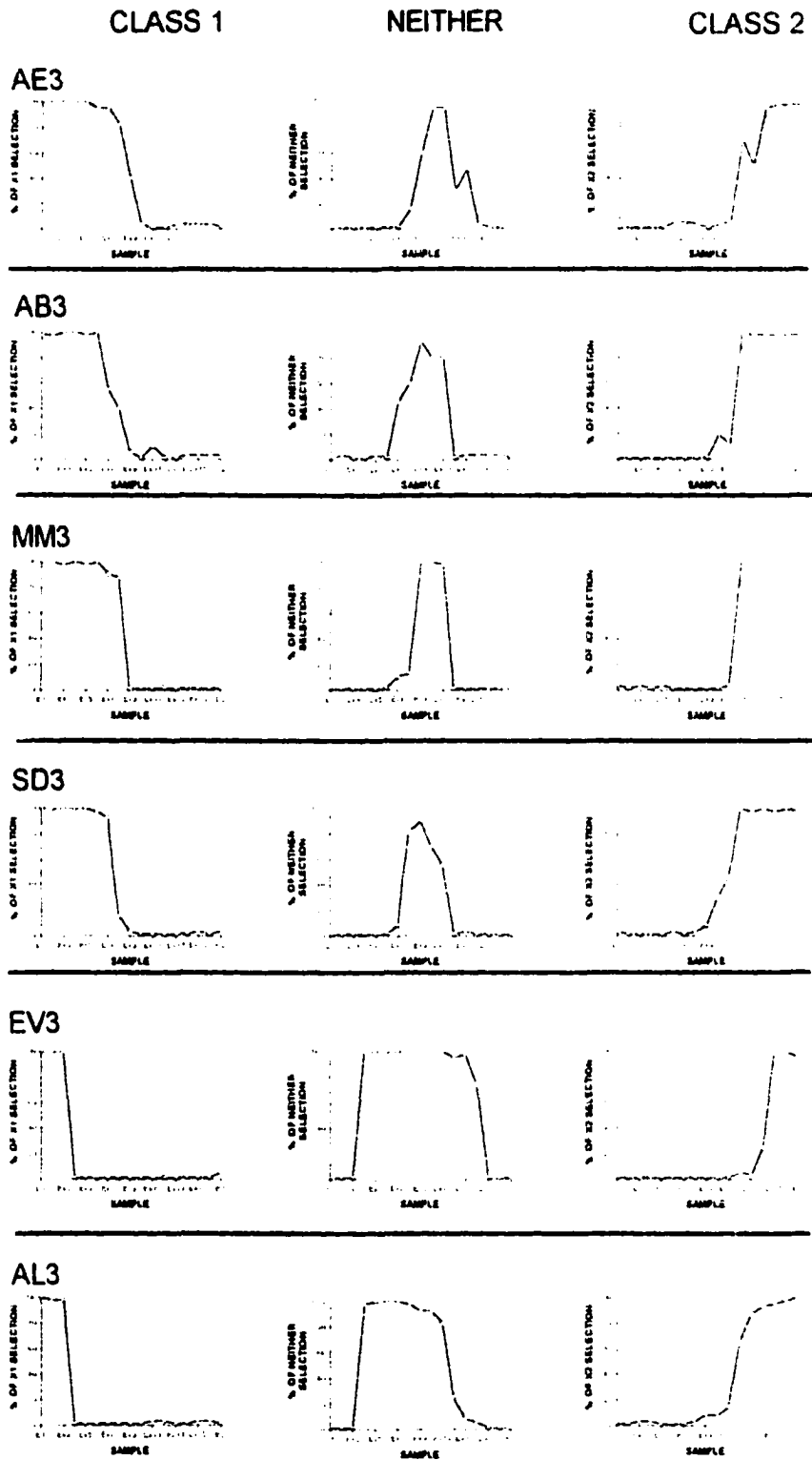


Figure 12. The width of perceptual classes (PC) compared to the width of corresponding generalized equivalence classes (GEC). Each open circle represents one class for a particular subject. The dashed diagonal line indicates a 1:1 correlation.

Figure 12.

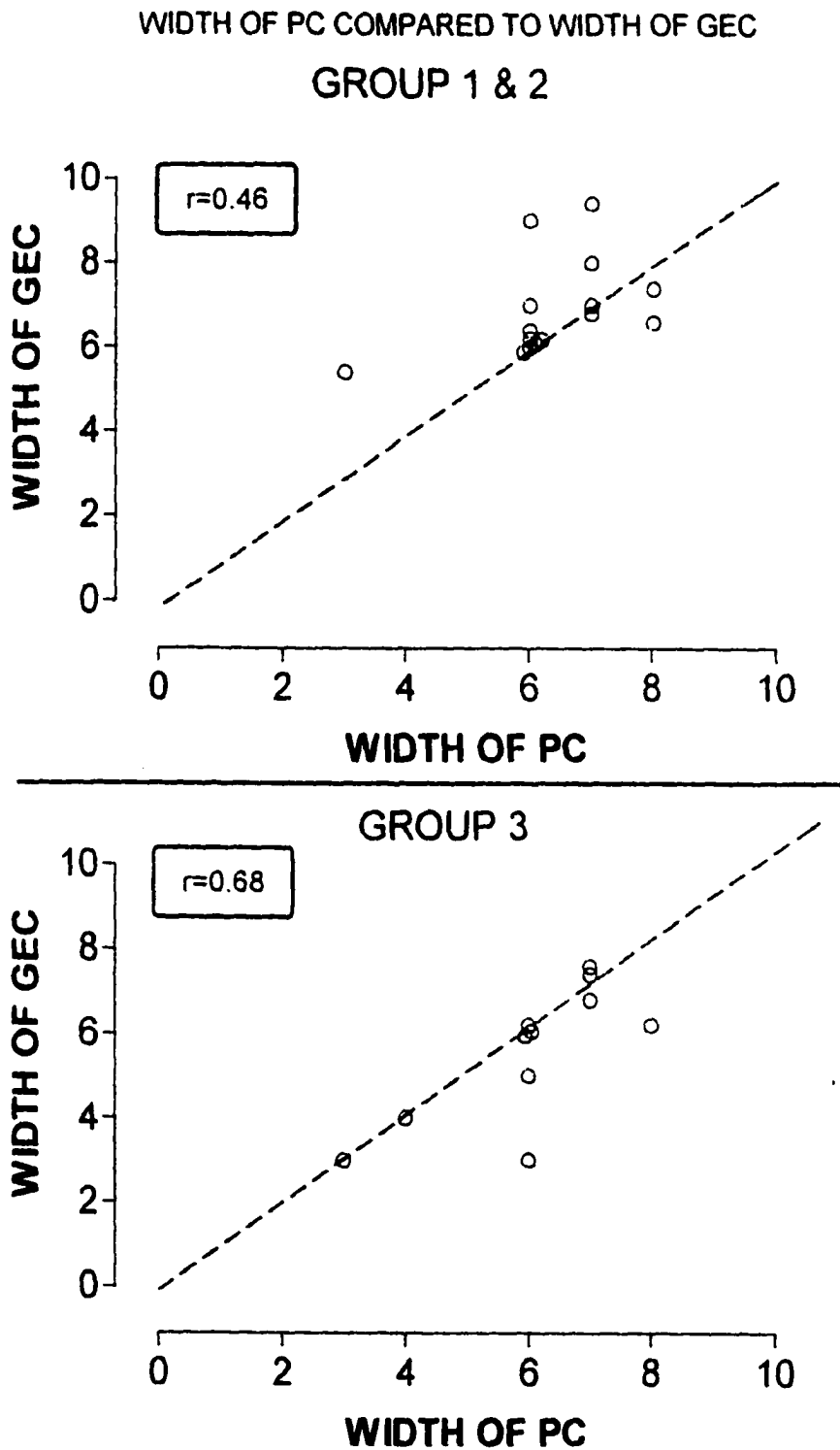


Figure 13. The results of the response transfer test for subjects in Group 1. Each graph plots the percentage of trials in which the subject produced a particular response as a function of the stimulus values presented during a trial. The vertical dotted lines indicate the boundaries of the perceptual classes as measured during the primary generalization test. The shaded bars indicate performance in the presence of members of the basal equivalence members, and the open circles indicate performance in the presence of variants of the E stimuli. The left column of graphs shows the results for the Class 1 response, the middle column of graphs shows the results for the selection of the neither response, and the right column of graphs shows the results for Class 2 response.

Figure 13.

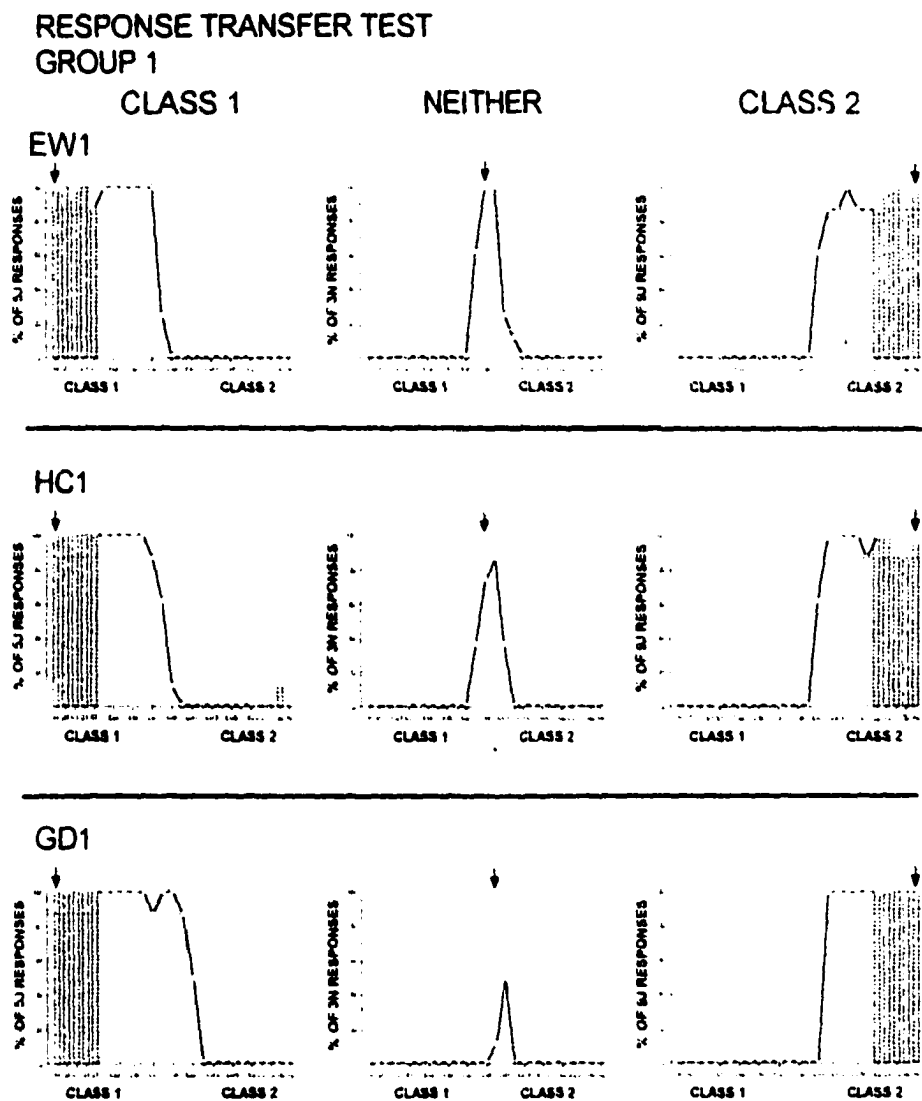


Figure 14. The results of the response transfer test for subjects in Group 2. The graphs are structured the same as those in Figure 13.

Figure 14.

RESPONSE TRANSFER TEST
GROUP 2

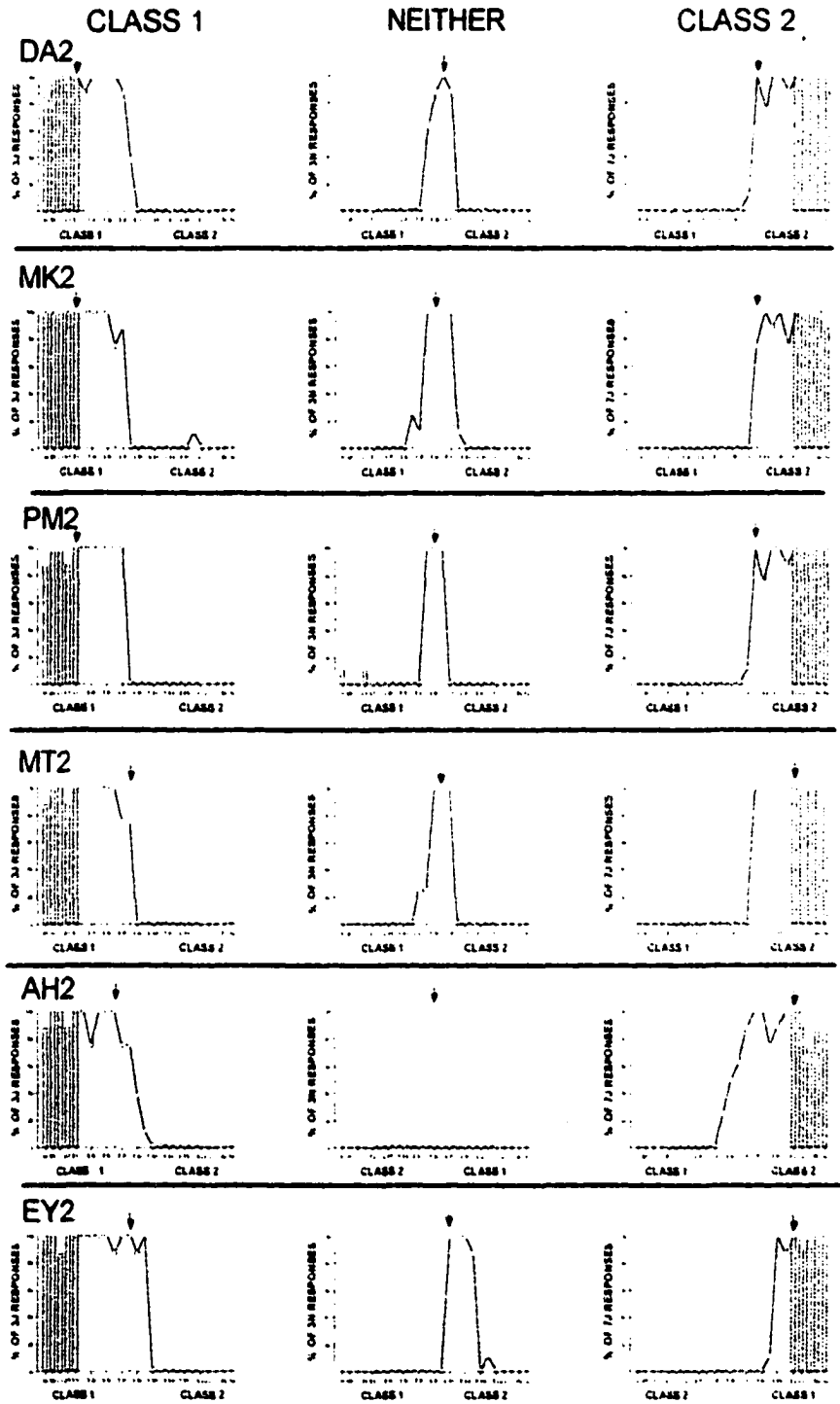


Figure 15. The results of the response transfer test for subjects in Group 3. The graphs are structured the same as those in Figure 13.

RESPONSE TRANSFER TEST
GROUP 3

Figure 15.

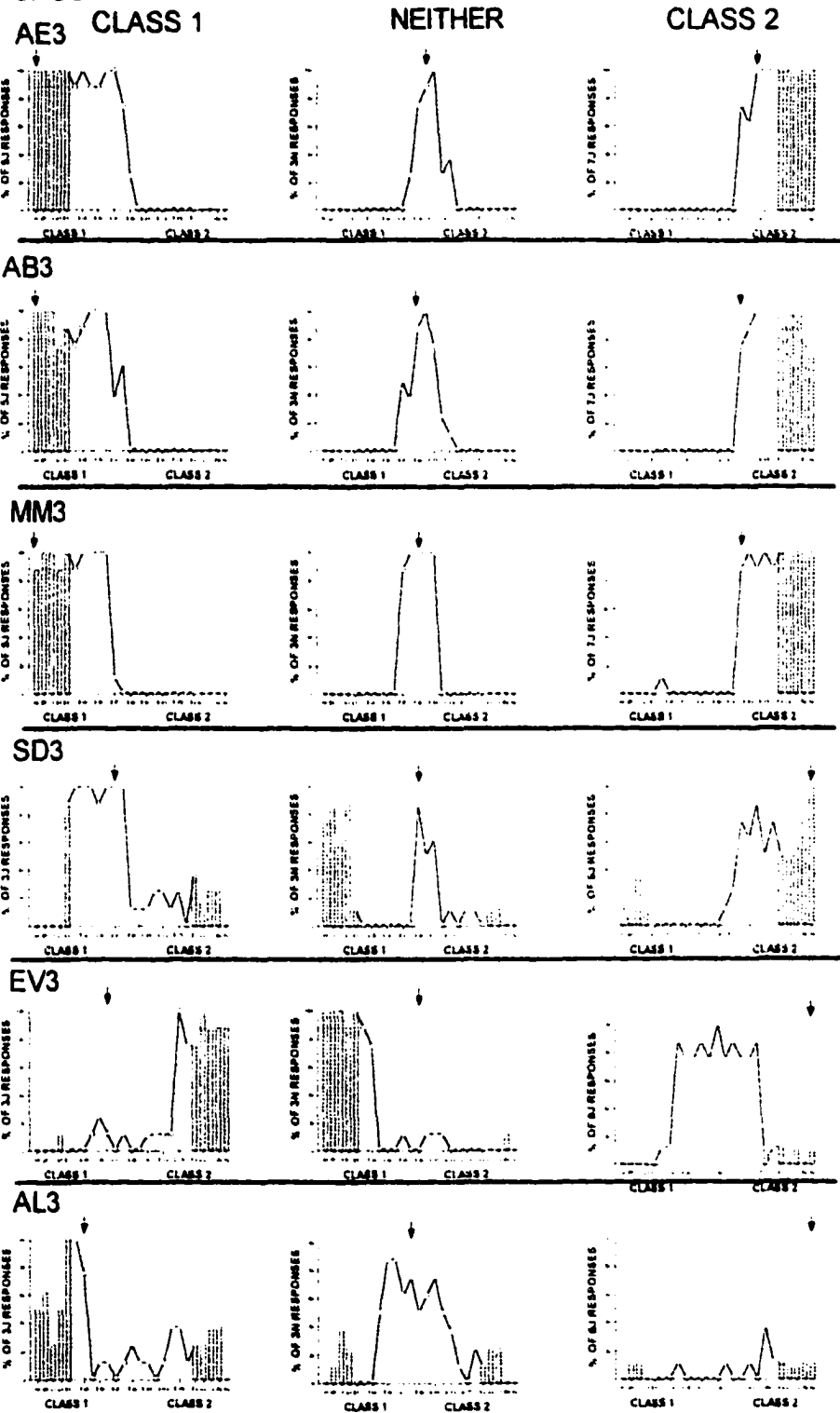
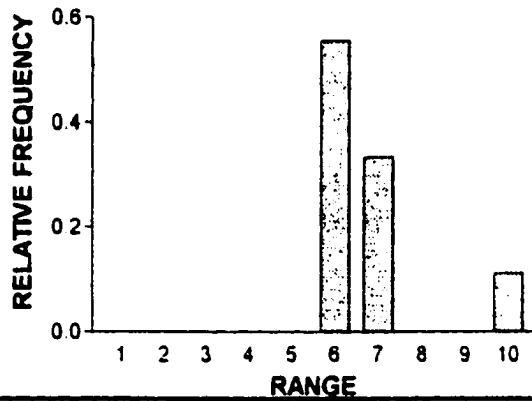


Figure 16. The relative frequency of the range of variants that occasioned response transfer when a response was trained to a particular stimulus.

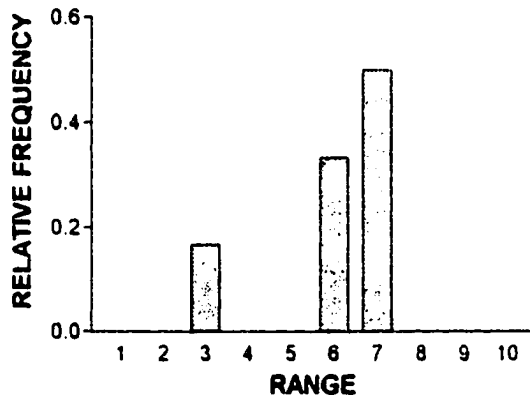
Figure 16.

RELATIVE FREQUENCY OF THE RANGE OF VARIANTS THAT OCCASIONED RESPONSE TRANSFER WHEN A RESPONSE WAS TRAINED TO A PARTICULAR STIMULUS

STIMULUS A



STIMULUS Ea



STIMULUS Eb

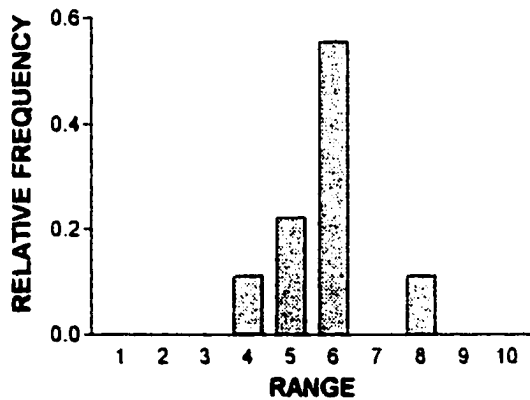
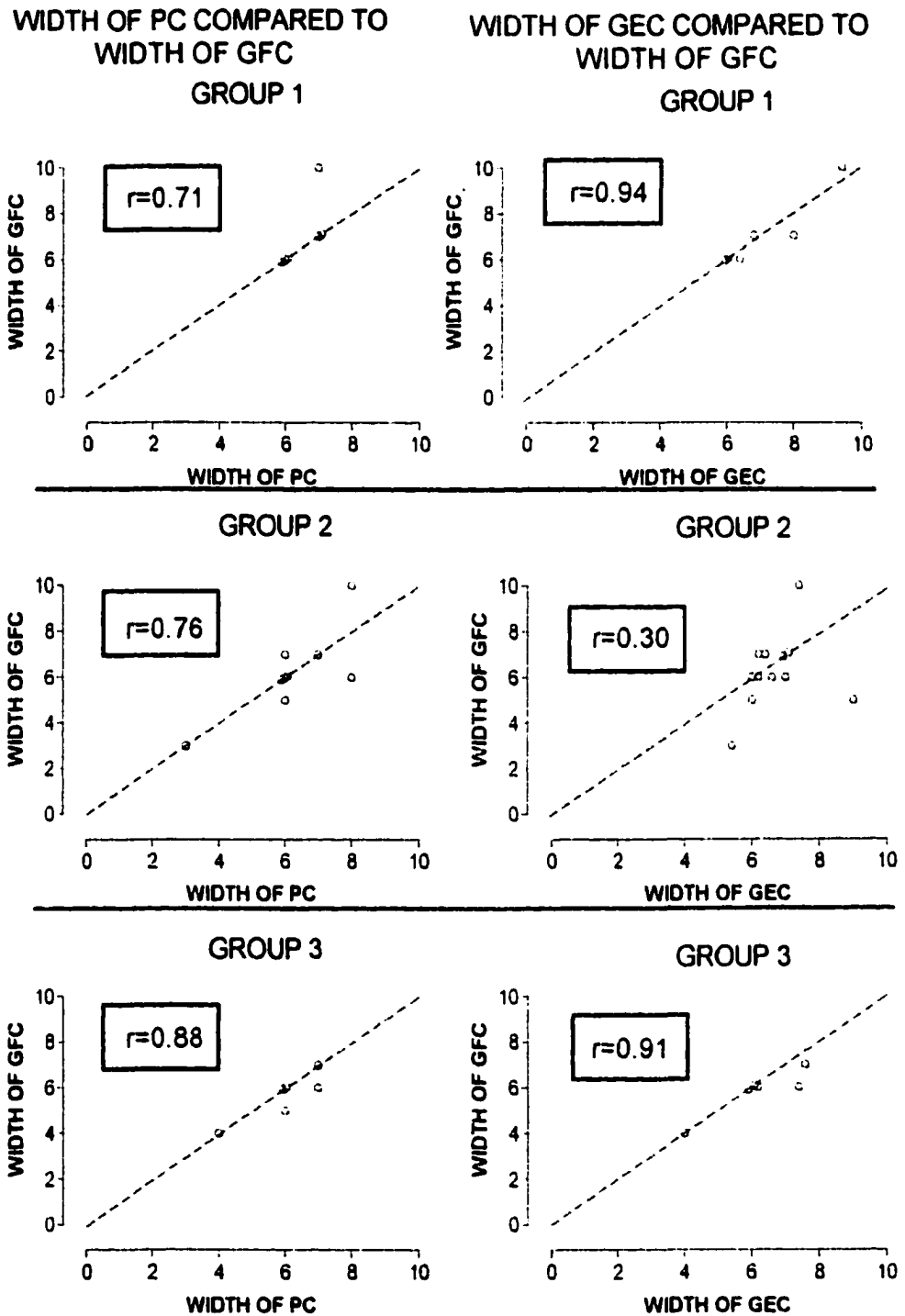


Figure 17. The left column of graphs compare the widths of perceptual classes (PC) with corresponding generalized functional classes (GFC). The right column of graphs compare the width of generalized equivalence classes (GEC) with corresponding generalized functional classes. The graphs are structured the same as those in Figure 12.

Figure 17.



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