JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 2009, **91,** 225–251 NUMBER 2 (MARCH)

OPTIMIZING LINKED PERCEPTUAL CLASS FORMATION AND TRANSFER OF FUNCTION

LANNY FIELDS[1] AND MICHELLE GARRUTO[1,2]

[1]THE GRADUATE SCHOOL OF THE CITY UNIVERSITY OF NEW YORK
[2]QUEENS COLLEGE OF THE CITY UNIVERSITY OF NEW YORK

A linked perceptual class consists of two distinct perceptual classes, A′ and B′, the members of which have become related to each other. For example, a linked perceptual class might be composed of many pictures of a woman (one perceptual class) and the sounds of that woman's voice (the other perceptual class). In this case, any sound of the woman's voice would occasion the selection of any picture of the woman and vice versa. In addition, after learning to name the woman in the presence of one picture, that name would be uttered when presented with all of the images of the woman's face and all of the sounds of her voice. This study involved 15 participants and sought to (a) maximize the percentage of participants who formed linked perceptual classes, and (b) determine whether those classes acted as transfer networks, that is, whether the discriminative function of one class member would generalize to other members of the class and not to members of a different class. The rate of emergence of each linked perceptual class was maximized by establishing a single class-linking conditional relation between the clearest member of one class used as a sample stimulus and the most ambiguous member of the other class used as a comparison stimulus. Class formation was demonstrated using the serial and programmed presentation of A′–B′ probes that consisted of untrained pairs of stimuli drawn from the A′ and B′ classes. Most participants showed immediate emergence of the two linked perceptual classes. The remaining participants showed delayed emergence following a second exposure to each originally error-producing probes. Once the linked perceptual classes had emerged, a differential response to a specific member of one perceptual class generalized mostly or completely to the other members of that linked class and rarely, if ever, to members of the other linked class. Thus, generalization did not depend on the specific class members that had been used for discrimination training.

Key words: linked perceptual classes, generalized equivalence classes, response transfer, generalization, delayed and immediate emergence, function-transfer networks, keyboard responses, humans

---

A linked perceptual class consists of two distinct perceptual classes where the members of one class occasion the selection of members of the other class (Fields & Reeve, 2000, 2001). A perceptual class consists of a range of stimuli that can be arrayed along a continuum, all of which evoke the same response or the mutual selection of each other (Fields & Reeve, 2000, 2001). For example, a linked perceptual class might consist of one perceptual class containing many pictures of a woman's face taken from many angles and focal lengths, and another perceptual class contining the sound of the woman's voice while speaking, whispering, shouting, singing, etc. The stimuli in both perceptual classes are acting as members of a single linked perceptual class if any of the sounds of the woman's voice occasion the selection of any of the pictures of the woman and vice versa. In addition, after learning to name the woman in the presence of one of the pictures, that same name would be evoked by all of the pictures of the woman's face in the first perceptual class and all of the sounds of her voice in the second.

The formation of a linked perceptual class, then, is an example of the union of two perceptual classes to form a single class (Sidman, 1994). This behavioral phenomenon has also be referred to as intersensory integration and cross-modal perception (Bahrick & Pickens, 1994). A second example involves the sounds of a predator such as leopards and the odors they emit. Were a prey animal to learn to flee when confronted with one of those sounds and generalize that same response to the odors, this might enhance the prey animal's survival. Yet another example, this from the

This research was conducted with support from Contract DASW01-96-K-0009 from the U.S. Army Research Institute, and by PSC-CUNY Research Awards 68547, 69567, and 61617. We thank Xiqiang Zhu for his assistance in the development of the software used to conduct the experiment and analyze the data reported herein. We acknowledge Michael Marroquin and Patricia Moss for their assistance in the collection and analysis of the data presented above.

Correspondence and reprint requests may be addressed to Lanny Fields, Department of Psychology, Queens College/CUNY, 65-30 Kissena Boulevard, Flushing, New York 11367 (e-mail: lanny.fields@qc.cuny.edu).

doi: 10.1901/jeab.2009.91-225

field of medical diagnostics, would be the sensations produced by benign and malignant tumors when palpated (one perceptual class) and X-ray images that correspond to each class of tumor (the other perceptual class). The control of behavior by linked perceptual classes may be universal, at least in humans. Understanding how these classes are formed would strengthen a behavior-analytic account of the development of behavioral repertories that are based on the formation of complex stimulus classes (Critchfield & Fienup, 2008; Dymond & Rehfeldt, 2000; Hayes, Barnes-Holmes, & Roche, 2001; Leslie, 2002; Mackay & Fields, in press; Sidman, 1994, 2000; Tonneau, 2001).

Thus far, only four published studies have considered linked perceptual classes either theoretically or empirically. Fields and Reeve (2001) described the relation of linked perceptual classes to perceptual classes, equivalence classes, and generalized equivalence classes, as well as intersensory integration and cross-modal perception. In a second study, Fields et al. (2002) described a testing procedure for tracking the emergence of a linked perceptual class. A subsequent study (Fields et al., 2005) identified the effects of different testing procedures on the rate of emergence of a linked perceptual class. The fourth study identified the effects of variables used in the training procedure on the emergence of such classes (Fields et al., 2007). To date, no studies have identified a combination of training and testing procedures that optimizes the formation of linked perceptual classes. This was the focus of the present experiment.

Variables that Influence Class Formation

Understanding the variables that influence the formation of linked perceptual classes requires use of the extensive set of terms set forth in Figure 1. The stimuli contained in two distinct perceptual classes can be represented by A′ and B′. A linked perceptual class can be represented as A′==B′. Three specific stimuli in each perceptual class are designated as the *anchor*, *midpoint*, and *boundary* stimuli. The anchor stimulus is the clearest (that is, least ambiguous) stimulus in a perceptual class. The boundary stimulus is the most ambiguous stimulus in the class, that is, it is the stimulus most distant from the anchor stimulus that always occasions the selection of all other

A1’=B1’ A1b---A1m---A1a ➔ B1b---B1m---B1a

A2’=B2’ A2b---A2m---A2a ➔ B2b---B2m---B2a

Fig. 1. Two linked perceptual classes—A1′–B1′ and A2′–B2′—are presented. Aa, Am and Ab represent the anchor, midpoint, and boundary stimuli, respectively, in perceptual class A′, and Ba, Bm and Bb represent the anchor, midpoint, and boundary stimuli in perceptual class B′. The numerals 1 and 2 designate different perceptual classes, each of which occupies a different region of the A or B Domain. The arrows join the stimuli that are used as sample and comparison stimuli in the conditional discrimination task by which the two perceptual classes were formed (see the procedure used in Phase 4).

stimuli in the same perceptual class in a matching-to-sample context (Cumming & Berryman, 1965). The midpoint stimulus is perceptually equidistant from the anchor and boundary stimuli. In the A′ class, the anchor, midpoint, and boundary stimuli are represented symbolically as Aa, Am, and Ab, respectively. For the B′ class, they are represented symbolically as Ba, Bm, and Bb. The operations used to identify the anchor, midpoint, and boundary stimuli in a perceptual class will be described in the Method section.

Figure 1 also illustrates how two linked perceptual classes can be formed. Assume the presence of four distinct perceptual classes: A1′, A2′, B1′, and B2′. Two perceptual classes may become linked by establishing at least one conditional discrimination that involves a stimulus in one of the classes (e.g., A1′) and a stimulus in another (e.g., B1′). In this example, the conditional discrimination might consist of a sample that is the anchor stimulus of the A1′ class (A1a) and a comparison that is the boundary stimulus of the B′ class (B1b). At the same time, another conditional discrimination could be established using the anchor stimulus of the A2′ class (A2a) and the boundary stimulus of the B2′ class (B2b). As previously indicated, these conditional discriminations would be established using a matching-to-sample format. For example, A1a or A2a would be presented as the sample stimulus with B1b and B2b as the pair of comparison stimuli. In this procedure the selection of B1b in the presence of A1a and B2b in the presence of A2a would be reinforced.

The formation of a linked perceptual class can be studied by measuring performance in the presence of novel ''cross-class'' probes that are derived from the two perceptual classes used in conditional discrimination training. Each probe contains a new combination of the anchor, midpoint, and boundary stimuli from the A′ and B′ classes. From these two perceptual classes 18 cross-class probes are possible: Aa–Ba, Am–Ba, Ab–Ba, Aa–Bm, Am–Bm, Ab–Bm, Ab–Bb, Am–Bb, Ab–Bb, Ba–Aa, Bm–Aa, Bb–Aa, Ba–Am, Bm–Am, Bb–Am, Ba–Ab, Bm–Ab, and Bb–Ab. The actual set of cross-class probes would not include those used in the original discrimination training. The probes also are presented in a matching-to-sample format. The reliable formation of a linked perceptual class (A1′==B1′) would be demonstrated if most or all of the cross-class probes produced selection of the appropriate comparison stimulus when they were presented. The viability of this approach was demonstrated by Fields et al. (2002).

The formation of linked perceptual classes consists of a training phase and a testing phase. Fields et al. (2005) examined the effect of variables in the training phase on the formation of linked perceptual classes while the training phase was held constant across different testing conditions. Specifically, two perceptual classes were linked by the establishment of the two conditional discriminations Aa→Ba and Ab→Bb. About 50% of the participants formed a linked perceptual class when the test block included several different probes, or when a succession of test blocks was presented in which each test block contained a different cross-class probe and the blocks were presented in a random order. By contrast, 88% of the participants formed linked perceptual classes when the test blocks contained the same probe in each block, and the blocks were presented in a sequence that minimized changes in the stimuli used in adjacent blocks. This arrangement was conceptually similar to the simple-to-complex protocol that optimizes the formation of equivalence classes (Adams, Fields, & Verhave, 1993).

Fields et al. (2007) examined variables in the training phase on the formation of linked perceptual classes while the testing condition was held constant across different training conditions. About 70% of the participants formed linked perceptual classes after the two perceptual classes were linked by the establishment of two conditional discriminations (Aa→Ba and Ab→Bb, or Aa→Ba and Ab→Ba) or by the establishment of a single conditional discrimination (Aa→Bb). Many fewer participants formed linked perceptual classes when training involved other types of conditional discriminations (i.e., Aa→Ba, Ab→Bb, or Ab→Ba).

Fields et al. (2005) did not specify whether the effects of variations in the testing condition were confined to the single training condition that was used in their experiment. Likewise, Fields et al. (2007) did not determine whether the effects of variations in the training condition were limited to the single testing condition they used. The present experiment was designed to determine how the formation of linked perceptual classes is influenced when the training condition (Aa→Bb) that optimized the formation of linked perceptual classes in Fields et al. (2007) is combined with the optimal testing condition identified by Fields et al. (2005). A comparison of the outcome of the present study with those of the two earlier studies might indicate whether the optimal training and testing conditions function additively or interactively.

In earlier studies that tracked the formation of linked perceptual classes, immediate emergence was demonstrated when the at least 17 of 18 serially presented cross-class probes used to document class formation produced class-indicative responding. If performances failed to meet that criterion, it was still possible for the linked perceptual class to emerge on a delayed basis. For some participants in the Fields et al. (2007) study, errors occurred to the cross-class probes presented early in the testing condition, though not to the probes presented later. However, the authors did not reexpose participants to the earlier probes to confirm that they, too, now produced correct responses. In the present experiment, the re-presentation of failed probes was used to confirm the delayed emergence of the linked perceptual classes.

Generalization of the Discriminative Function in Linked Perceptual Classes

Once a perceptual class has formed, it typically acts as a function-transfer network (Tonneau, 2001). For example, after a response reliably occurs to one class member, it will reliably occur to the other class members but not to members of other perceptual classes. That is, the discriminative function acquired by one class member transfers or generalizes completely to the other members of the same perceptual class but not to those in different classes. Indeed, generalization (or function transfer) has been used to define a stimulus class (Goldiamond, 1962; Keller & Schoenfeld, 1950; Lea, 1984; Tonneau, 2001). The generalization or transfer of discriminative function has been demonstrated among the members of perceptual classes (Cook & Katz, 1999; Wasserman, Kiedinger, & Bhatt, 1988), fuzzy or ill-defined classes (Rosch & Mervis, 1975; Watanabe, 2001), polymorphous classes (Jitsumori, 1993, 1994; Lea & Harrison, 1978), equivalence classes (Sidman & Cresson, 1973; Sidman, Wynne, Maguire, & Barnes, 1989), functional classes (Wirth & Chase, 2002), and generalized equivalence classes (Belanich & Fields, 1999, 2003). However, it has not yet been studied with linked perceptual classes.

The second focus of the present experiment was to determine whether the generalization of discriminative function established for one member of a linked perceptual class generalized only to the other members of the same linked perceptual class but not to those in other linked perceptual classes. After the establishment of two linked perceptual classes, a single member of each was trained in a new conditional discrimination. Subsequently, a generalization test involving the new discrimination was conducted in which members of each linked perceptual class were presented in the absence of reinforcement. If responding occurred to the members of the same linked perceptual class but not to members of the other linked perceptual class, this finding would provide evidence that linked perceptual classes are also function-transfer networks.

The study of generalization of discriminative function in linked perceptual classes is complicated by the fact that any stimulus in a linked perceptual class can be used as the sample stimulus for the response. Most studies of generalization of function have measured transfer from only one stimulus in a linked perceptual class. One exception was a study conducted by Belanich and Fields (2003), who measured generalization of discriminative function using several stimuli in a generalized

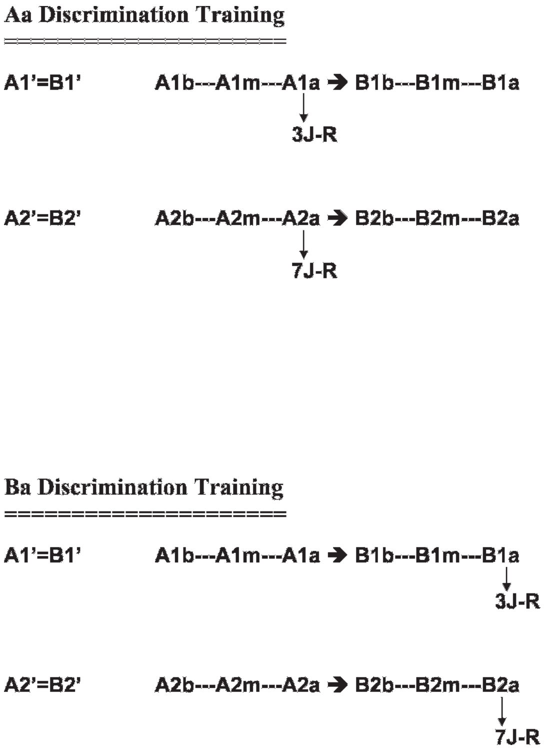

Fig. 2. In Aa discrimination training (upper figure) the 3 J and 7 J responses were trained to the Aa stimuli in linked perceptual classes 1 and 2, respectively. In Ba discrimination training (lower figure), 3 J and 7 J responses were trained to the Ba stimuli in linked perceptual classes 1 and 2, respectively.

equivalence class. They found generalization when the response was trained to one stimulus in the class but not when it was trained to more than one stimulus. Thus, it is possible that the generalization of discriminative function may vary according to the actual position of the stimulus to which a response is trained, that is, to its position within the linked perceptual class (Fields & Verhave, 1987).

Figure 2 illustrates linked perceptual classes that differ in terms of the class member used for discrimination training. The anchor stimuli in the A′ classes (A1a and A2a) are directly linked to the boundary stimuli of the B classes (B1b and B2b, respectively) and thus are closest to the members of the B′ classes. Conversely, the anchor stimuli of the B′ classes (B1a and B2a) are furthest removed from the stimuli in the A′ classes. In the present experiment, generalization among the stimuli within a linked perceptual class was evaluated by training responses to the Aa stimulus (as illustrated in the upper portion of Figure 2) or the Ba stimuli (as illustrated in the lower portion of Figure 2) in different experimental groups. The results should indicate whether the generalization of the discriminative function to the other stimuli in a given linked perceptual class depends on the location within the linked perceptual class of the specific stimulus used in training.

METHOD

Participants

Twenty undergraduate students enrolled in a psychology course at Queens College served as the participants in the experiment. They received partial course credit upon its completion. The experiment was completed in two or three 1–2 hr sessions. All participants read and acknowledged the Informed Consent Statement given to them before the start of the experiment.

Ten participants were assigned randomly to each of two experimental groups. The data for 4 participants had to be eliminated due to errors in programming. One participant dropped out of the experiment, leaving experimental groups with 8 and 7 participants, respectively.

Apparatus

Hardware and software. The experiment was conducted with an IBM-compatible computer that displayed all stimuli on a 15-in color monitor. Responses consisted of touching specific keys on a standard QWERTY keyboard. The experiment was controlled by custom software that programmed all stimulus presentations and recorded all keyboard responses.

Stimuli. All stimuli were presented in 5-cm × 5-cm colored squares (without contrasting borders) against a black background on the computer monitor. Sets of related common English words were used for keyboard familiarization training. Figure 3 illustrates the stimuli from the four domains that were used for the preliminary training phase and the two domains that were used in the main phase of the experiment. The stimuli were presented as multicolored RGB 24-bit images. Domains W, X, Y, Z, A, and B were referred to otherwise as Female–Male, Abstract Pictures, Truck–Car, North Korea–Germany, Tree–Cat, and Haiti–California, respectively. The stimuli in the North Korea–Germany and Haiti–California domains were banded elevation satellite images of 100 km × 100 km of the designated geographical regions. In these images, elevation is represented by a color gradient.

The stimuli that were the endpoints (anchors) of each domain are depicted in rows _1a and _2a in Figure 3. Stimuli that varied systematically between the endpoints of each domain were created with a commercially available morphing software program (Figuracion, 1998). Called variants, these stimuli in a domain were produced by superimposing the endpoint stimuli and changing their relative saliencies. Each variant was assigned a unit value that indicated its relative position along a continuous program-generated dimension. For stimuli in Domains W, X, Y, Z, and B, the software assigned values 000 and 500 to the endpoint stimuli and generated 498 variants between these endpoints. The variants used in the experiment had unit values of 030, 070, 100, 130, 170, 210, 250, 280, 310, 340, 370, 390, 430, and 470. For stimuli in Domain A, the software assigned unit values of 00 and 50 to the endpoint stimuli, and also generated 49 variants between these endpoints. The variants used in the experiment had unit values of 03, 06, 09, 12, 15, 18, 21, 25, 28, 31, 34, 37, 40, 43, and 47.

The endpoint stimuli in each domain were assigned the lowest and highest unit values, as already noted, and were designated as members of Perceptual Classes 1 and 2, respectively. Thus, the anchor stimuli in Classes 1 and 2 in Domain W were designated W1a and W2a. The anchor stimuli in Classes 1 and 2 for each domain are illustrated in the top and bottom rows of Figure 3. The variant most distant from the anchor stimulus of a class but still judged to be related to the anchor stimulus of that class was referred to as its boundary (b) stimulus (see below for details of the perceptual judgment procedure). Thus, the boundary stimuli in Classes 1 and 2 in Domain W were designated as W1b and W2b, respectively. The boundary stimuli for Classes 1 and 2 for each domain are illustrated in rows _1b and _2b in Figure 3. By definition, the anchor stimulus was perceived as the clearest in its perceptual class and the boundary stimulus as the most ambiguous member of the same class. The variant judged to be perceptually

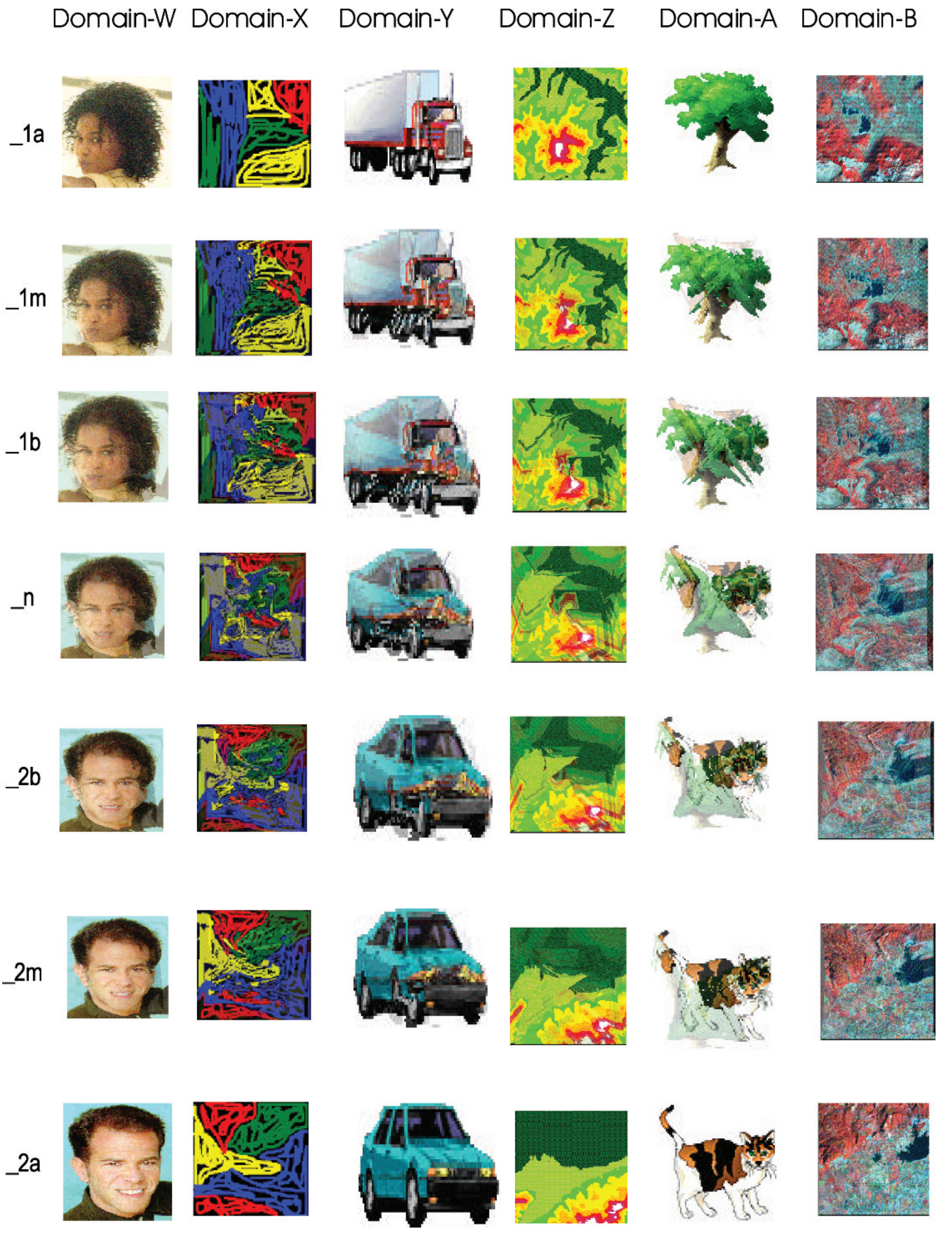

Fig. 3. The anchor, midpoint, boundary, and NEITHER stimuli used in the experiment. See text for details.

equidistant between the anchor and boundary stimuli within a class was referred to as its midpoint (m) stimulus. The midpoint stimuli in Classes 1 and 2 in Domain W were designated as W1m and W2m, respectively. The midpoint stimuli for Classes 1 and 2 for each domain are illustrated in rows _1 m and _2 m in Figure 3. The variants between the boundaries of the two classes in a domain were not considered to be members of either class. The variant judged to be perceptually equidistant between the boundaries of the two classes in a domain was called the neither (_n) stimulus for the domain (Adams, et al., 1993; Fields, Adams, Brown, & Verhave, 1993). For Domain W, the neither stimulus was designated as Wn and appears for each domain in row _n in Figure 3.

The unit values assigned to the variants used as midpoint, boundary, and neither stimuli in Domains W through Z were defined by a group of five independent observers using a bisection procedure. For a given domain, an observer was shown the anchor stimulus for Class 1, and then was asked to sort through the remaining variants and select the variant that was most distant from the anchor but was still related to it. The unit value of the variant selected was then designated as the boundary stimulus for Class 1. Each observer was then shown the anchor and boundary stimuli of Class 1, was asked to sort through the variants between them, and then to select the variant that was perceptually equidistant from each. The unit value of that variant became the midpoint stimulus of Class 1. After doing the same for Class 2, the observer was presented with boundary stimuli from Classes 1 and 2 and asked to sort through the variants between the boundaries and select the variant that was equidistant from each. The unit value of that variant became the neither stimulus for that domain. The unit values selected by the observers were averaged for each midpoint and each boundary stimulus for each class and domain and for the neither stimulus in a domain. The stimuli associated with the resultant means are illustrated in rows _1 m through _2 m for Domains W, X, Y, and Z in Figure 3. The variants that approximated the midpoints, boundaries, and neither stimuli in Domains A and B. were based on performances in Phase 3 of the experiment (see below) and thus could vary with each participant. Those that appear in the figure are representative.

Procedure

Trial formats. The experiment was conducted with trials presented in a matching-to-sample format (Cumming & Berryman, 1965) during some phases and in a simple successive discrimination format during other phases. The matching-to-sample format used in Phases 1, 2, 3, 4, 5, and 8 involved the presentation of a sample stimulus and three comparison stimuli. The sample was presented in the upper portion of the monitor screen and was centered horizontally. The positive and negative comparisons were presented below the sample and to the left and right of the sample with the upper edges of the comparisons below the lower edge of the sample. The right edge of the left comparison was to the left of the left edge of the sample, and the left edge of the right comparison was to the right of the right edge of the sample. On any trial, the location of each comparison stimulus in the two comparison positions was determined randomly.

The sample was drawn from one of two sets of stimuli. One comparison was drawn from the same set as the sample on that trial and was called the positive comparison (Co+). The other comparison was drawn from the other set and was called the negative comparison (Co−). On some trials, a third comparison was also displayed on the computer monitor. Called the NEITHER comparison and represented symbolically as NC, it was included in a trial by displaying the phrase ''If NEITHER press 4''. That phrase was located between and below the Co+ and Co− stimuli. The selection of the NC implied that neither of the other two comparisons was related to the sample on that trial. It is important to note that the NEITHER comparison was not the same as the neither stimulus (−n) in a domain that was described previously.

A trial began when ''Press ENTER'' appeared on the screen. Pressing the ENTER key cleared the screen and displayed a sample. Pressing the space bar displayed two comparisons while the sample remained on the screen. During a trial, the Co+ or Co− stimulus was selected by pressing the 1 key for the comparison presented on the left and the 2 key for the comparison presented on the right. The selection of a comparison cleared the screen and immediately displayed a feedback message centered on the screen. When *informative* feedback was scheduled, a ''RIGHT'' or ''WRONG'' message appeared, depending on the accuracy of the comparison selection. The message remained on the screen until the participant pressed the R key for ''RIGHT'' or the W key for ''WRONG''.

During some training and all testing trials, *uninformative* feedback was presented following a comparison selection. This consisted of a dashed line on both sides of the letter E (i.e., - - E - -) and signaled the end of a trial. This cue remained on the screen until the participant pressed the E key, which served as an observing response to the uninformative feedback stimulus. After the observing response occurred, the screen was cleared, and the next trial began (cf. Fields et al., 1997).

Prior to using the uninformative feedback stimulus, participants were taught the meaning of the E stimulus with a block of conditional discrimination training trials that involved the presentation of E, R, or W as sample stimuli and the comparison stimuli RIGHT, WRONG, and End of Trial in combinations of two. Reinforcement was presented for the selection of RIGHT in the presence of R, WRONG, in the presence of W, and End of Trial in the presence of - - E - -.

The simple successive discrimination format used in Phases 6 and 7 of the experiment involved the presentation of single stimuli from each class in succession. Each stimulus presentation is called a trial. To terminate a trial, the participant had to emit an FR-3 response or an FR-7 response. The FR-3 response involved pressing the J key three times, followed by pressing the ENTER key. The FR-7 response involved pressing the J-key seven times followed by the ENTER key. The term ''response'' is appended to each FR designation because each string of N presses of the J-key followed by the pressing of the ENTER key explicitly defines the termination of the homogeneous chain of presses of the J-key (Mechner, 1994).

Trial blocks and feedback frequency. Each phase of the experiment consisted of blocks of trials. In all phases, the trials in a block were presented in a randomized order without replacement. At the start of training, a block was presented repeatedly with informative feedback after each comparison selection until all trials within the block produced the correct responding. This was referred to as the mastery criterion. Thereafter, the percentage of trials in a block that produced informative feedback was reduced to 75%, 25%, and finally to 0% as long as the mastery criterion was maintained. During the reduction in feedback, trials that produced informative feedback were randomly determined. Each block ended with the presentation of an on-screen message that read, ''Press ENTER to begin the next block.'' If 100% correct responding was not achieved within three blocks at a given feedback level during training, the participant was returned to the previous feedback level during the next block. In practice, this was a very infrequent occurrence.

Phase 1: Instructions and keyboard familiarization. Prior to the experiment, participants read the following set of instructions on the monitor screen:

> ''Thank you for volunteering to participate in this experiment. PLEASE DO NOT TOUCH ANY OF THE KEYS ON THE KEYBOARD YET! In this experiment you will be presented with many trials. Each trial contains three or four CUES. These will be familiar and unfamiliar picture images. YOUR TASK IS TO DISCOVER HOW TO RESPOND CORRECTLY TO THE CUES. Initially, there will also be INSTRUCTIONS that tell you how to respond to the cues, and LABELS that will help you to identify the cues on the screen. The labels and the instructions that tell you which KEYS to press will slowly disappear. Your task will be to RESPOND CORRECTLY to the CUES and the INSTRUCTIONS by pressing certain keys on the computer's keyboard. The experiment is conducted in phases. When each phase ends, the screen will sometimes tell you how you did. If you want to take a break at any time, please call the experimenter.''

All of the labels and instruction prompts alluded to in the instructions were presented on the screen and were deleted serially across trials. After pressing the space bar, (as prompted by an on-screen message) participants were trained to emit the appropriate keyboard responses to complete a trial. Sixteen trials, each containing three English words, such as KING, QUEEN, and CAMEL, were presented. The semantic relation between the sample word (e.g., KING) and one of the comparisons (e.g., QUEEN) was used to prompt the selection of the correct comparison. The words RIGHT or WRONG, which were used as informative feedback, followed each comparison selection (for additional details, see Fields et al., 1997).

Correct responding during Phase 1 was also facilitated by instruction prompts (e.g., ''Make your choice by pressing 1 or 2'' or ''Press the E key'') that were deleted in a serial manner across trials (see Fields, Adams, Verhave, & Newman, 1990, and Fields et al., 1997, for further details). Phase 1 ended when the stimuli were presented without prompts and when performance was at least 88% accurate (14 of 16 correct trials) during a single block. In the remaining phases, whenever a participant pressed a nonexperimentally defined key during a trial, the instruction prompt that accompanied the appropriate key press during Keyboard Familiarization reappeared on the screen during the next three trials.

Phase 2: Formation of perceptual classes in domains W–Z. Training began with stimuli in Domain W. The anchor, midpoint, or boundary stimulus from Classes 1 and 2 or the NEITHER stimulus were presented as the sample in randomized order across trials in the training block. On all trials, the comparisons consisted of the anchor stimulus and the NEITHER stimulus from the domain. Informative feedback ''RIGHT'' was presented for the selection of W1a when W1a, W1m, or W1b was the sample stimulus, for the selection of W2a when W2a, W2m, or W2b was the sample stimulus, and for the selection of the NEITHER comparison when Wn, the NEITHER stimulus, was the sample. Otherwise, ''WRONG'' was presented. The same block was repeated until the correct response occurred on all trials. The same procedure was then repeated with the stimuli in Domains X, Y, and Z. The final performances in each domain demonstrated that the three stimuli in each perceptual class within the domain produced the selection of the anchor stimulus from the same class, and the NEITHER stimulus produced the selection of the NEITHER comparison (NC), a phrase that was not from either class. In other words, the training procedure resulted in the formation of two functionally independent perceptual classes (Reeve & Fields, 2001) in each of the four domains.

Phase 3: Formation of perceptual classes in domains A and B. As mentioned in the Introduction, the stimuli from perceptual classes A′ and B′ were used as samples and comparisons in the cross-class probes that were used to document the formation of linked perceptual classes. Fields, Matneja, Varelas, and Belanich (2003) showed that the unit values of the midpoint and boundary stimuli of a perceptual class can differ depending on whether they serve as sample or comparison stimuli. In the present experiment, the unit values of the midpoint and boundary stimuli from domains A and B that were used as samples were established by generalization tests conducted with the variant-to-base procedure and the base-to-variant procedure.

During the variant-to-base procedure, the endpoints and variants in a domain (e.g., SAT-0 through SAT-500 for domain A) were presented as samples on different trials. In addition, the anchor stimuli from that domain (e.g., SAT-0 and SAT-500) and the NEITHER comparison were always presented as the three comparisons on all trials. Variants at one end of the domain were considered to be members of the same perceptual class if each of them produced the selection of the anchor-stimulus comparison at the same end of the domain on at least 88% of the test trials. The boundary stimulus for that class was the variant farthest away from the anchor stimulus. The midpoint stimulus for a class was the variant that was numerically equidistant in value between the anchor and the boundary stimulus for the class. Thus, the results of the variant-to-base procedure established the unit values for the midpoint and boundary stimuli that were used subsequently as samples.

In the base-to-variant test format, one of the anchor stimuli (i.e., SAT-0 or SAT-500 for Domain B) was presented as the sample on a trial. For each sample, the other anchor stimulus and the NEITHER comparison were presented as two of the three comparisons on all trials. The third comparison on each trial was one of the variants. Variants differed across trials on a random basis. The members of a perceptual class were the variants that were selected in the presence of the anchor stimulus on at least 88% of the test trials. The boundary stimulus for that class was the variant most removed from the anchor stimulus. The midpoint stimulus for a class was the variant that was numerically equidistant in value between the anchor and the boundary stimuli for a class. Thus, the results of the base-to-variant procedure established the unit values for the midpoint and boundary stimuli that were used subsequently as comparisons.

The variant-to-base and base-to-variant procedures alternated in separate blocks of trials, each of which included two presentations of all variants. Each block was presented four times using each procedure for a total of eight presentations of each variant. Participants were presented first with the eight test blocks that contained stimuli in the A domain and then with eight blocks that contained stimuli from the B domain. At the end of Phase 3 the four perceptual classes identified by the two procedures were designated A1′, A2′, B1′, and B2′.

Two dependent variables were measured during the variant-to-base tests and the base-to-variant tests: comparison selection on all trials, and the time that separated the presentation and selection of a comparison on each trial. Each temporal measure was used to determine the response time for each trial and was defined as the reciprocal of the above mentioned temporal value.

Phase 4: Linked perceptual class formation. Perceptual classes A1′ and B1′ and perceptual classes A2′ and B2′ each were linked by the establishment of the A1a–B1b and A2a–B2b conditional discriminations shown in the upper portion of Figure 2. This Aa→Bb training condition was used because it was previously shown to be the necessary and sufficient condition for the reliable formation of linked perceptual classes (Fields et al., 2007). The Aa–Bb links were established using trials in which the sample was either A1a or A2a, and the comparisons were always the pair of stimuli B1b and B2b. For example, when A2a was the sample, selection of B2b produced ''*RIGHT*'' on the computer screen. The selection of B1b produced ''*WRONG*.'' The block of trials was repeated with informative feedback on all trials until there was 100% accuracy. Thereafter, the percentage of trials in a block that occasioned feedback was systematically reduced as described above as long as performances remained 100% accurate. If the mastery criterion was not achieved by the completion of three blocks at a given level of feedback, the percentage of feedback was returned to its prior level.

The formation of linked perceptual classes was identified using novel cross-class probes and the 18/1-PRGM testing procedure described by Fields et al. (2005). Briefly, this testing procedure involved the presentation of cross-class probes in a serial and highly programmed order. They showed that the procedure substantially increased the percentage of participants who formed linked perceptual classes. The 18/1-PRGM procedure involved the presentation of one probe-type per test block. The probe types were introduced in the following order: Aa–Ba, Am–Ba, Ab–Ba, Aa–Bm, Am–Bm, Ab–Bm, Aa–Bb, Am–Bb, Ab–Bb, Ba–Aa, Bm–Aa, Bb–Aa, Ba–Am, Bm–Am, Bb–Am, Ba–Ab, Bm–Ab, and Bb–Ab. Specifically, the first nine test blocks were in the A′–B′ format and the second nine in the B′–A′ format. The anchor, midpoint, and boundary stimuli from the A1′ and A2′ classes served as samples in the first, second, and third test blocks, respectively. All three of these blocks contained the anchor stimuli from the B1′ and B2′ classes as the comparisons. The anchor, midpoint, and boundary stimuli from the A1′ and A2′ classes served as samples, while the midpoint stimuli from the B1′ and B2′ classes served as comparison stimuli in test blocks 4–6. Finally, the anchor, midpoint, and boundary stimuli from the A1′ and A2′ classes were again the samples in test blocks 7–9, respectively, and the boundary stimuli from the B1′ and B2′ classes served as the comparisons. The entire sequence was repeated during test blocks 10–18, with the A′ and B′ stimuli reversed as samples and comparisons.

The probe stimuli presented in test blocks 1–18 are listed in Table 1. For example, the Am–Bb probes in block 8 contained A1m or A2m as samples with B1b and B2b as the comparisons on all trials in addition to the NEITHER comparison. When A1a was the sample, a response to the B1b comparison stimulus was indicative of the emergence of one relation in a linked perceptual class, but a response to the B2b comparison was counter-indicative. Each probe was presented in a block of eight trials. Responding indicative of class formation required the selection of the comparison from the same class as the sample on at least seven of the eight trials in the block. This was the mastery criterion. A linked perceptual class was assumed to be formed when this criterion was satisfied for at least 17 of the 18 cross-class probes.

Table 1

Probe stimuli used to identify the acquisition of linked perceptual classes in Phase 4.

Test Block	Probe Type/ Block	Class 1 Probes				Class 2 Probes			
		Sa	Co+	Co−	Co−	Sa	Co+	Co−	Co−
1.	Aa→Ba	A1a	B1a	B2a	NC	A2a	B2a	B1a	NC
2.	Am→Ba	A1m	B1a	B2a	NC	A2m	B2a	B1a	NC
3.	Ab→Ba	A1b	B1a	B2a	NC	A2b	B2a	B1a	NC
4.	Aa→Bm	A1a	B1m	B2m	NC	A2a	B2m	B1m	NC
5.	Am→Bm	A1m	B1m	B2m	NC	A2m	B2m	B1m	NC
6.	Ab→Bm	A1b	B1m	B2m	NC	A2b	B2m	B1m	NC
7.	Aa→Bb	A1a	B1b	B2b	NC	A2a	B2b	B1b	NC
8.	Am→Bb	A1m	B1b	B2b	NC	A2m	B2b	B1b	NC
9.	Ab→Bb	A1b	B1b	B2b	NC	A2b	B2b	B1b	NC
10.	Ba→Aa	B1a	A1a	A2a	NC	B2a	A2a	A1a	NC
11.	Bm→Aa	B1m	A1a	A2a	NC	B2m	A2a	A1a	NC
12.	Bb→Aa	B1b	A1a	A2a	NC	B2b	A2a	A1a	NC
13.	Ba→Am	B1a	A1m	A2m	NC	B2a	A2m	A1m	NC
14.	Bm→Am	B1m	A1m	A2m	NC	B2m	A2m	A1m	NC
15.	Bb→Am	B1b	A1m	A2m	NC	B2b	A2m	A1m	NC
16.	Ba→Ab	B1a	A1b	A2b	NC	B2a	A2b	A1b	NC
17.	Bm→Ab	B1m	A1b	A2b	NC	B2m	A2b	A1b	NC
18.	Bb→Ab	B1b	A1b	A2b	NC	B2b	A2b	A1b	NC

Note. Sa = sample stimulus. NC = NEITHER comparison. Letters a, m, and b = anchor, midpoint, and boundary stimuli, respectively.

Phase 5: Reexposure to cross-class probes. If a probe did not meet the mastery criterion in Phase 4, it was presented again in Phase 5. If at least 17 of the 18 probes presented in Phases 4 and 5 satisfied the mastery criterion, we considered the A′ and B′ classes to have become members of a single linked perceptual class. At this point, participants whose performance had documented the emergence of a linked perceptual class were introduced to Phase 6 of the experiment. Those whose performance failed to produce a linked perceptual class were excused from the experiment.

Phase 6: Discrimination training. As previously mentioned, the participants were randomly assigned to two experimental groups. Groups Aa and Ba contained 7 and 8 participants, respectively. Discrimination training was preceded with the presentation of the following instructions: ''In the next phase of the experiment you will be presented with two cues in a random order. During one cue the correct response involves pressing the J-key three times followed by pressing the enter key. During the other cue, the correct response involves pressing the J-key seven times followed by pressing the enter key. Your task is to discover and make the correct response to each cue. ''

Discrimination training was then conducted using a successive discrimination format that involved the random presentation of two stimuli without replacement. For Group Aa, the two stimuli were the anchor stimuli in the two A classes (A1a and A2a; see Table 2). For Group Ba, the two stimuli were the anchor stimuli in the two B classes (B1a and B2a). Training was conducted in blocks of trials, with half of the trials containing the stimulus from Linked Perceptual Class 1 and the other half containing the stimulus from Linked Perceptual Class 2. When stimulus A1a was presented, for example, the feedback word ''*RIGHT*'' was displayed after making an FR-3 response. In contrast, the feedback word ''*WRONG*'' was displayed for making any other response. When stimulus A2a was presented, the feedback word ''*RIGHT*'' appeared after the participant made an FR-7 response. ''*WRONG*'' was displayed for making any other response. Feedback occurred on all trials throughout training until the participant responded with 100% accuracy on all trials in a block. This constituted the mastery criterion. Once it was reached, feedback was provided on 75%, then

Table 2

Boundaries of perceptual classes A1′, A2′, B1′, and B2′ measured with variant-to-base (VB) and base-to-variant (BV) tests for participants in each group.

		A1′		A2′		B1′		B2′	
Condition	Participant	VB	BV	VB	BV	VB	BV	VB	BV
Aa	2895	15	25	34	40	170	130	310	370
	2887	12	9	43	43	130	130	340	340
	2893	15	15	40	34	130	170	340	370
	2896	15	15	40	40	170	170	310	310
	2891	15	12	40	43	100	100	310	340
	2892	21	21	34	28	130	210	340	340
	2885	12	18	37	34	170	250	310	280
Ba	2898	12	15	40	37	170	170	340	340
	2900	9	9	43	43	70	70	310	310
	2901	18	37	40	25	170	170	310	280
	2912	12	9	40	40	170	130	340	340
	2914	15	15	34	40	100	130	430	370
	2913	25	25	34	34	210	170	340	310
	2911	12	15	34	40	210	170	280	370
	2897	21	21	34	34	170	210	340	340

25%, and finally 0% of the trials in a block as long as 100% accuracy was maintained. If accuracy dropped below 100% in two successive blocks, participants were exposed to a block that used the next higher feedback level.

Phase 7: Generalization test. A generalization test was conducted to determine the extent to which the stimuli in one linked perceptual class (e.g. A1′–B1′) would generalize within the class but not to the other class (A2′–B2′). The generalization test also utilized a successive procedure. The test was conducted in blocks of 12 trials. Each block contained 12 stimuli: the anchor, midpoint, and boundary stimuli from each of the two linked perceptual classes. The stimuli were presented in a randomized sequence without replacement and with extinction in effect, that is, there was no feedback. The block was repeated eight times. Thus, each stimulus was presented eight times. If most of the stimuli in a linked perceptual class produced the same response that had been trained in Phase 6, and that response was not produced by stimuli from the other linked perceptual class, then the former class was identified as a function-transfer network.

Phase 8: Maintenance test for linked perceptual classes. The purpose of the final phase was to evaluate the integrity of the linked perceptual classes after the generalization test, and was a replication of the testing procedure used in Phase 4.

RESULTS

Perceptual Class Formation

Contiguous stimuli along a continuum function as a perceptual class when they produce the same response in the absence of direct training, while other stimuli along that continuum do not produce that response. The stimuli included in the A1′, A2′, B1′, and B2′ classes were identified using the results from Phase 3 of the experiment. The data from Participant 2897 for the B1′ and B2′ classes were representative of those for all the participants and are shown in Figure 4.

With the variant-to-base procedure the widths of perceptual classes were identified with the data presented in the three panels in the left-hand column. As seen in the top panel, the anchor stimulus in the B2′ class (SAT-500) was selected on at least 88% of trials in the presence of variants SAT-340 through SAT-500. Thus, those variants functioned as members of the B2′ class, and SAT-340 was the boundary stimulus. A similar pattern was occasioned by the variants at the other end of Domain B, which were used to define membership in the B1′ class. As seen in the bottom panel, the anchor stimulus in the B1′ class (SAT-0) was selected on at least 88% of trials in the presence of variants SAT-0 through SAT-170. Thus, those variants were considered members of the B1′ class with SAT-170 as its boundary.

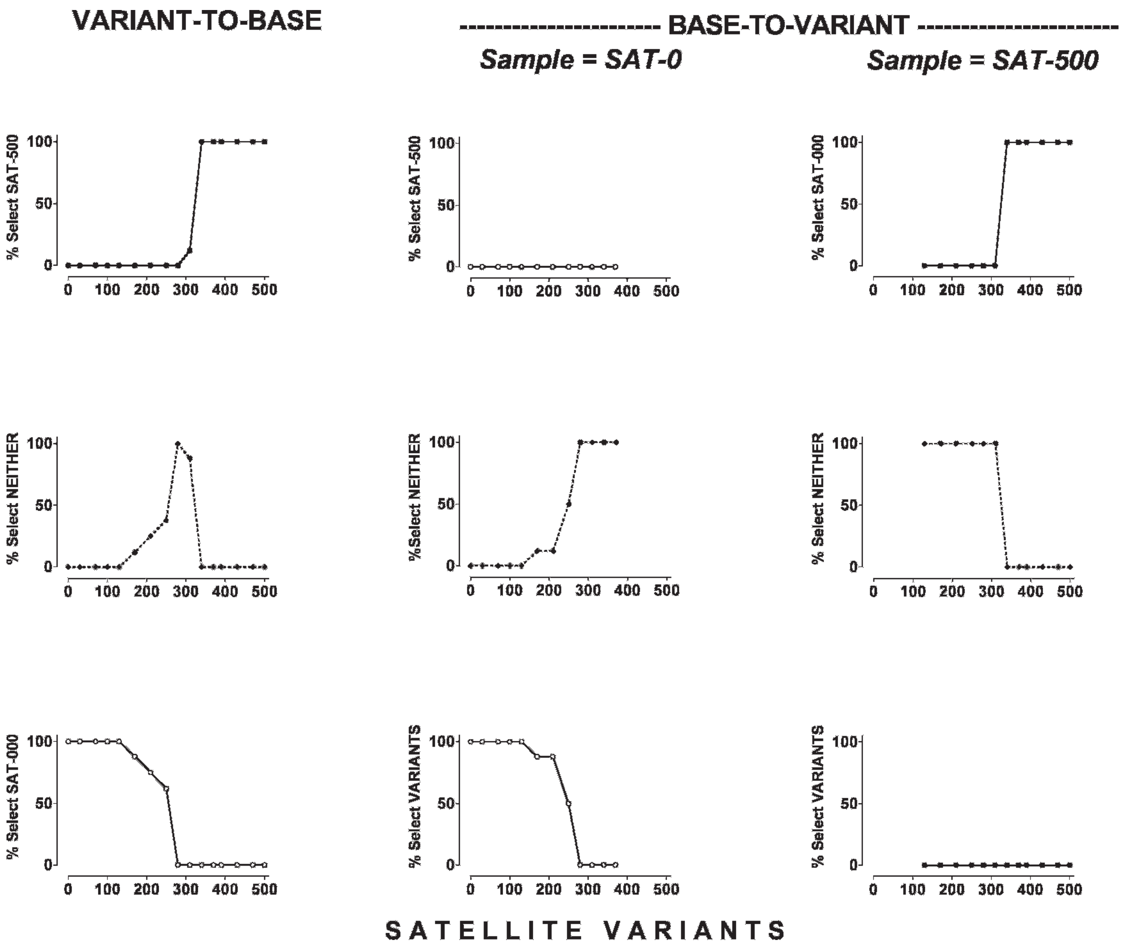

Fig. 4. The results of the variant-to-base and base-to-variant tests for Participant 2897 in Phase 3 of Experiment 1. See text for details.

When the base-to-variant procedure was used, the width of the B1′ class was identified using the data presented in the panels in the center column. During these tests, each trial involved the presentation of SAT-0 as the sample, with a different variant as one comparison and SAT-500 and NC as the other comparisons. The bottom panel shows that the variants from SAT-0 to SAT-210 were selected on at least 88% of trials in the presence of SAT-0, the anchor stimulus in the B1′ class. Thus, those variants functioned as members of the B1′ class with SAT-210 as its boundary.

The width of the B2′ class was identified using the data presented in the panels in the right-hand column. During this test, each trial involved the presentation of SAT-500 as the sample, with the three comparison stimuli: a different variant as one comparison, SAT-0 as the second comparison, and finally the NEITHER comparison. The top panel shows that the variants from SAT-500 to SAT-340 were selected on at least 88% of trials in the presence of SAT-500. Thus, those variants were members of the B2′ class with SAT-340 as its boundary.

Functional independence of perceptual classes. It could be argued that only one perceptual class was formed in each of the A and B domains and that the second class was actually all the other stimuli that were not members of the first class. Whether one or two classes had formed can be determined by examining the responses to stimuli beyond the boundary stimuli in the two putative classes. The existence of two classes would be confirmed if the decline in the selection of stimuli in one was not complemented by the selection of stimuli from the other class.

Figure 4 shows responses to the comparisons that lay beyond the boundary of a class. When variant-to-base tests were conducted (see left panel) as the variants moved below the boundary of the B2′ class (SAT-340), the selection of SAT-500 declined precipitously (top graph) and was accompanied by an increase in the selection of the NEITHER comparison (middle graph) at that point. In contrast, there was no selection of the SAT-0 comparison until SAT-250 (bottom graph).

When the base-to-variant procedure was used with SAT-0 as the sample (see middle panel), the selection of variants greater than SAT-170 (see bottom graph) was accompanied by an increase in the selection of the NEITHER comparison (middle graph) but no selection of SAT-500 (top graph). When SAT-500 was the sample (right panel), a rapid decline in the selection of variants less than SAT-340 (top graph) was accompanied by an increase in the selection of the NEITHER comparison (middle graph) and no selection of SAT-0 (bottom graph).

Overall, the decreases in the selection of stimuli from one class was accompanied by a concurrent increase in the selection of the NEITHER comparison rather than an increase in the selection of variants from the other end of the domain. This finding supports the view that the perceptual classes that formed were functionally independent of each other.

Boundary stimuli of perceptual classes. The width of a perceptual class was defined by the difference in the values of its anchor and boundary stimuli. Since the values of the anchor stimuli were fixed, the width of each class effectively was indexed by the values of the boundary stimuli. The values obtained from the variant-to-base and base-to-variant procedures for each perceptual class and each participant are listed in Table 2. For Domain A, which had endpoint values of 0 and 50 units, the boundary stimuli of the A1′ and A2′ classes averaged 16 and 38 units, respectively, with an average width of 22 units. For Domain B, which had endpoint values of 0 and 500 units, the boundary stimuli of the B1′ and B2′ classes averaged 155 and 332 units, respectively, and had an average width of 177 units.

Discriminability of stimuli in perceptual classes. To claim that stimuli are members of a perceptual class, some behavior must generalize between them, and some members must also be discriminable from each other (Fields et al., 2002; Fields & Reeve, 2001; Keller & Schoenfeld, 1950; Lashley & Wade, 1946; Lea, 1984; Wasserman et al., 1988). Stimuli are discriminable if they occasion different responses, the same response with different likelihoods (Belanich & Fields, 2003; Reeve & Fields, 2001), different reaction times (Bentall, Jones, & Dickins, 1999; Blough, 1978; Flynn, 1943), or different response speeds (Fields et al., 2002; Fields et al., 2005; Spencer & Chase, 1996). Response speed is the reciprocal of the time between the responses to the sample and the comparison on a trial.

In the present experiment, discriminability within the A1′, A2′, B1′, and B2′ perceptual classes was assessed in terms of the response speeds to the anchor, midpoint, and boundary stimuli during the generalization tests in Phase 3. The data were aggregated across participants, domains, classes, and test type because these variables did not produce systematic differences in the response speeds evoked by particular stimuli in a class. Average response speed was fastest for the anchor stimuli (1.0 s), slower for the midpoint stimuli (0.88 s), and slowest for the boundary stimuli (0.56 s). Since response speed is the reciprocal of latency, shorter latencies correspond to higher response speeds. The response speeds were significantly different from each other, $F(2) = 73.11$, $p < .0001$. Newman-Keuls post hoc tests of pairwise comparisons showed significant differences in the response speeds for the anchor and midpoint, $q = 5.393$, $p < .001$, midpoint and boundary, $q = 11.36$, $p < .001$, and anchor and boundary stimuli, $q = 16.75$, $p < .001$.

Immediate and Delayed Emergence of Linked Perceptual Classes

The procedures used to establish linked perceptual classes were the same for all participants. Data showing the immediate emergence of linked perceptual classes are summarized in Figures 5 and 6, while data showing the delayed emergence of linked perceptual classes are presented in Figures 7 and 8.

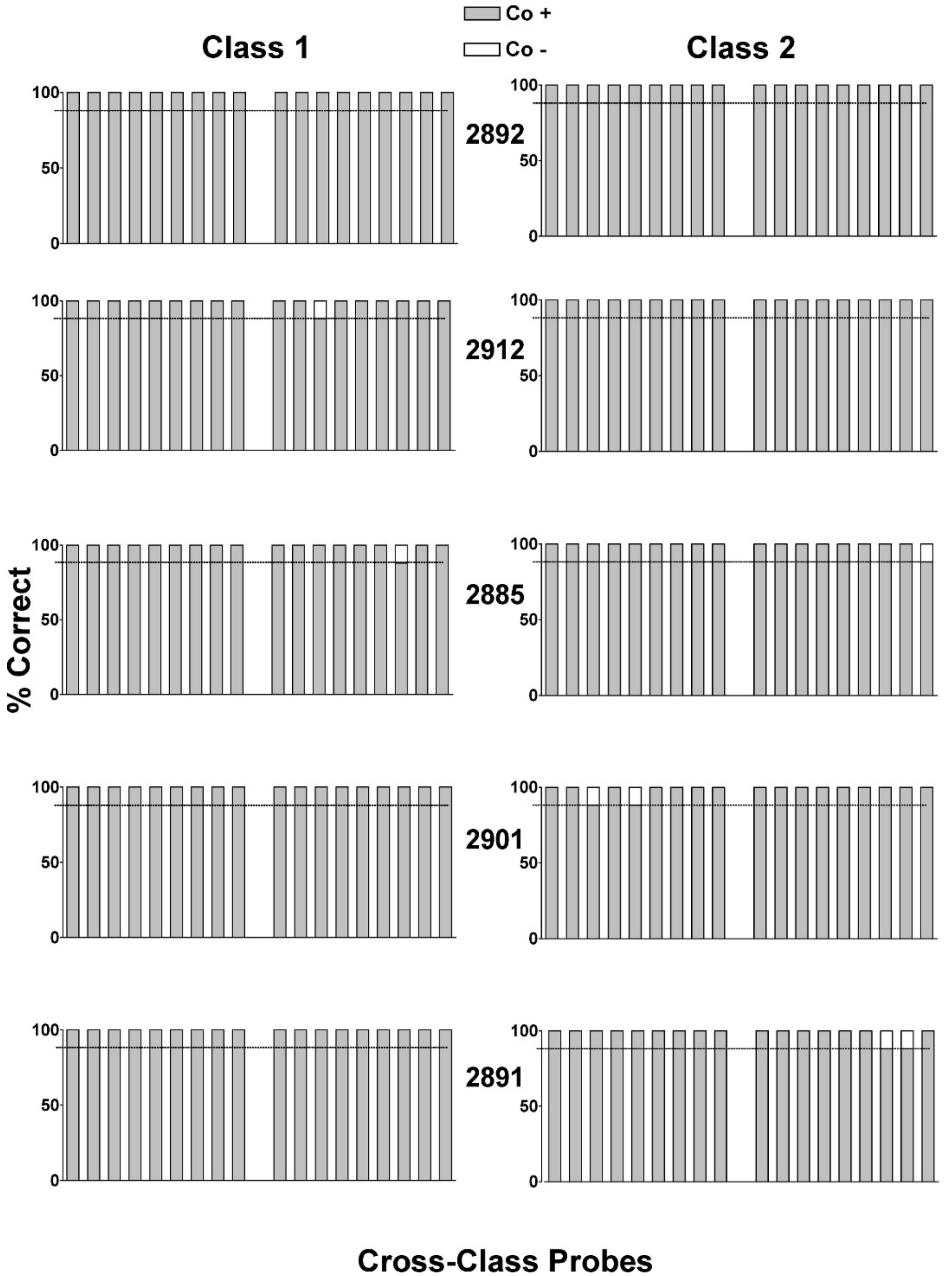

Fig. 5. Results from Phase 4 that indicate the formation of linked perceptual classes. The data in each row are for individual participants. The panels in the left and right columns correspond to linked perceptual classes 1 and 2, respectively. In each panel, the cross-class probes are listed from left to right in their order of presentation. The particular stimuli used as samples and comparisons in each probe are detailed in Phase 4 of the Method section.

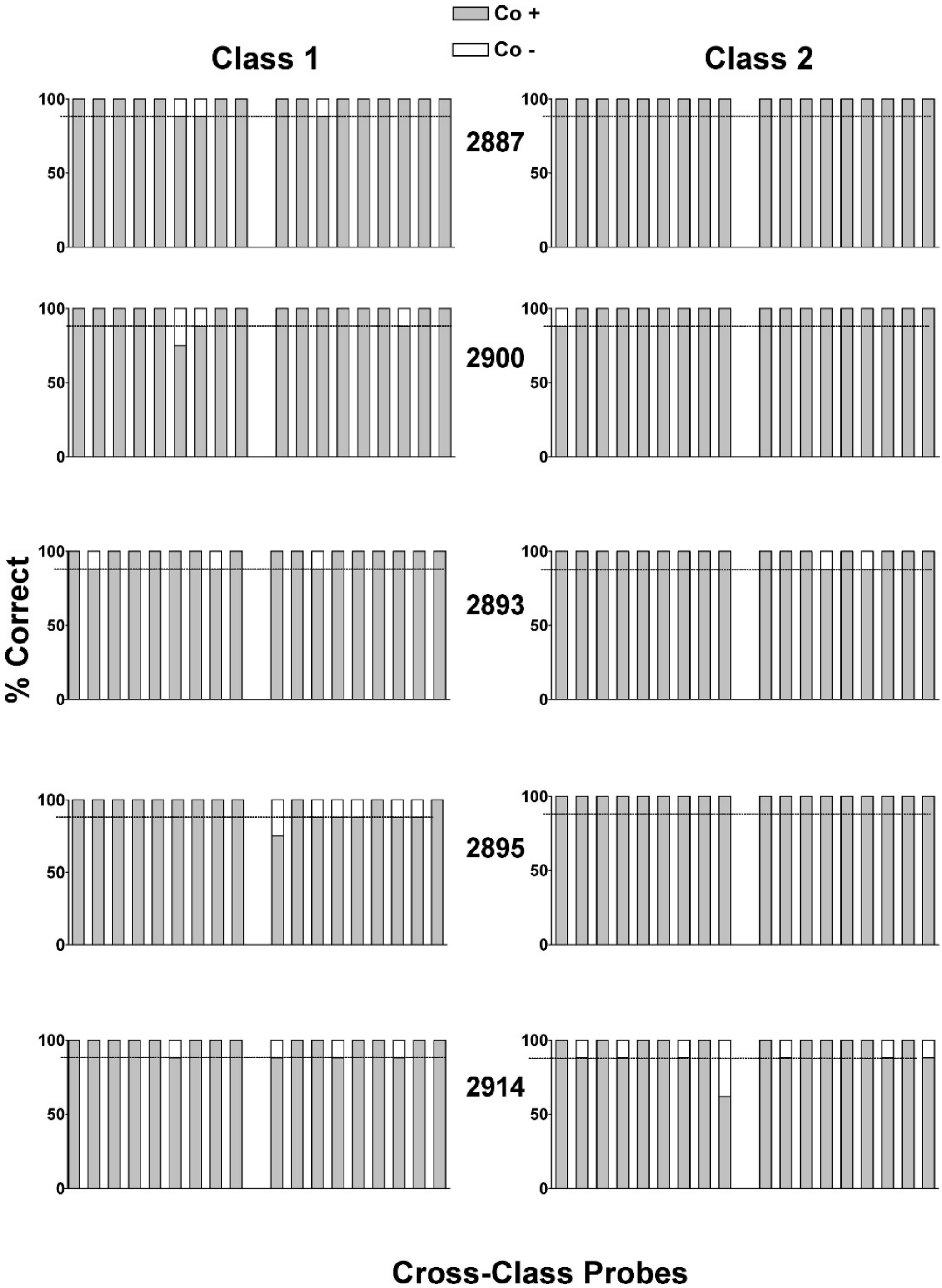

Fig. 6. Results for more of the participants in Phase 4 who formed linked perceptual classes. See Figure 5 for more information.

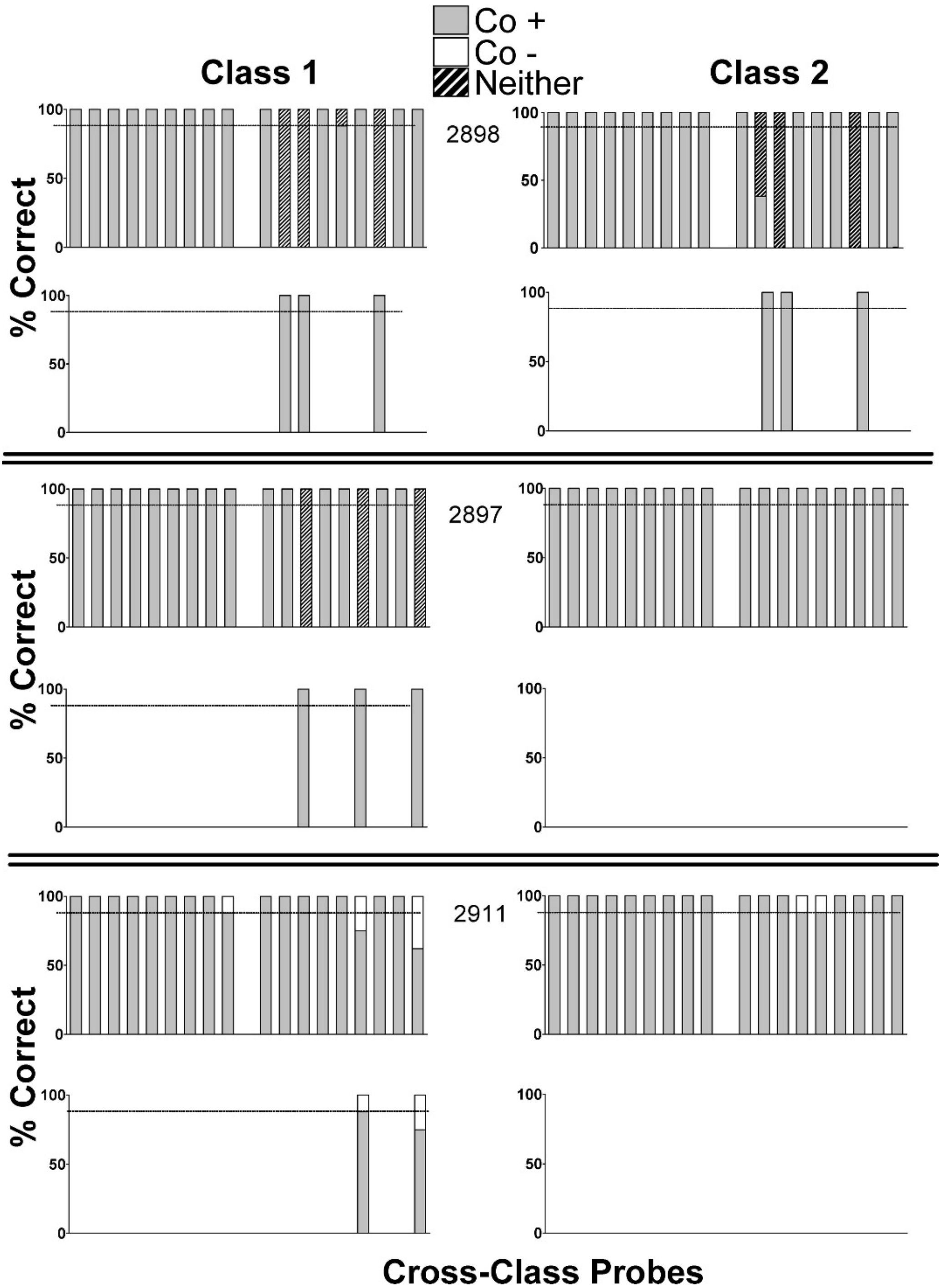

Fig. 7. Results for participants who showed the delayed emergence of linked perceptual classes. The data for each participant are presented in pairs of rows. For each participant, the panels in the top row present the results from Phase 4 (initial exposure to the cross-class probes), and the panels in the bottom row present the data from Phase 5 (reexposure to the failed probes).

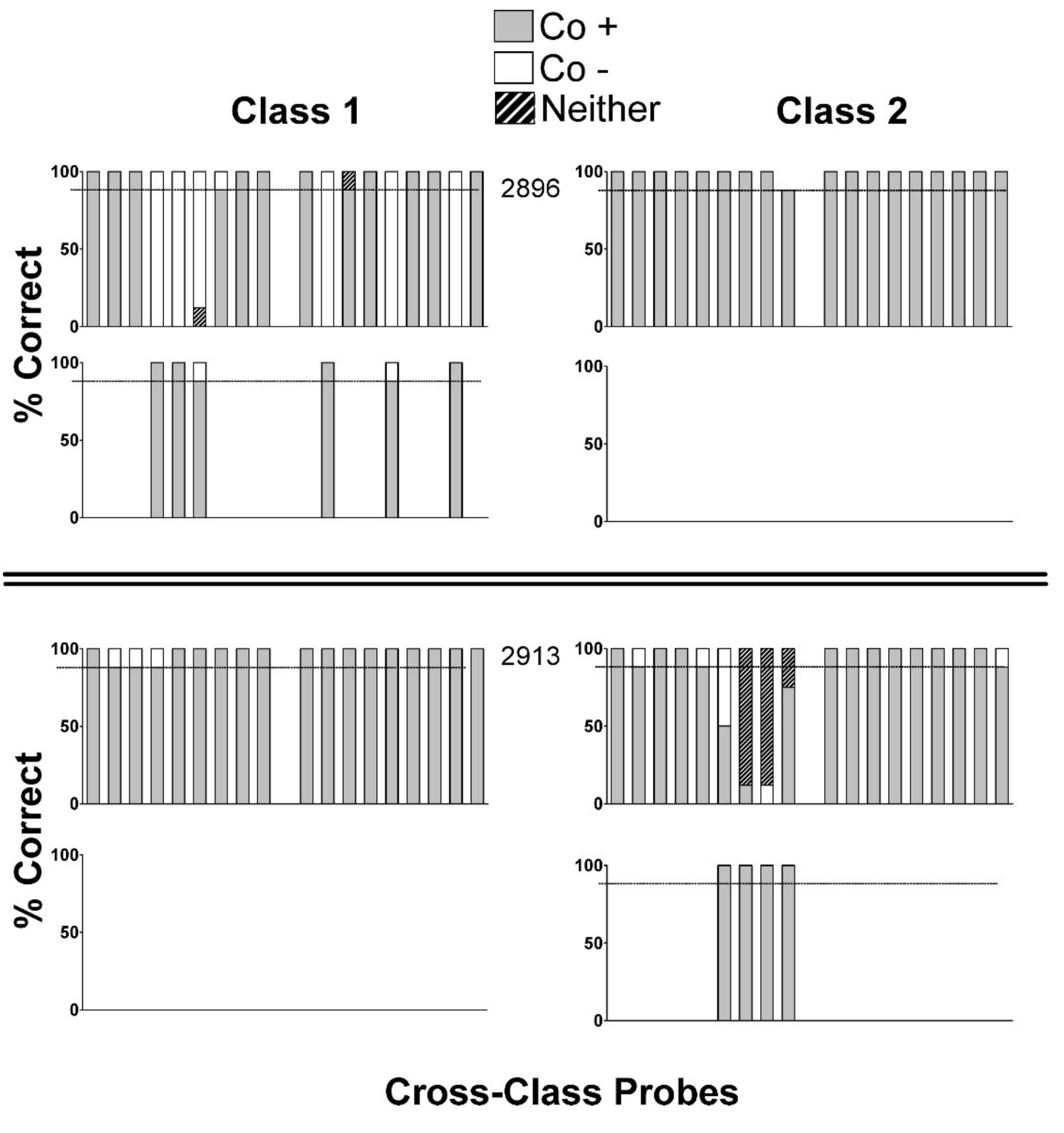

Fig. 8. Results for 2 more participants who showed the delayed emergence of linked perceptual classes. See Figure 7 for more information.

Ten participants (2891, 2892, 2893, 2895, 2887, 2885, 2901, 2912, 2900, and 2914) formed both linked perceptual classes in Phase 4. The data for each participant are presented on separate rows in Figures 5 and 6. The left and right panels display the results for linked perceptual classes 1 and 2, respectively. In each panel, the 18 cross-class probes are listed from left to right along the abscissa in the sequence that corresponds to their order of presentation. The dashed line at 88% indicates the mastery criterion. For 7 of the participants (2982, 2912, 2885, 2901, 2891, 2887, and 2893), the mastery criterion was satisfied for all 18 cross-class probes. For the 3 remaining participants (2895, 2900, 2914), the criterion was satisfied by all 18 probes in one class and 17 of the 18 probes in the other. For each of these participants, both of the linked perceptual classes emerged on an immediate basis.

For the remaining 5 participants (2898, 2897, 2911, 2896, and 2913), at least one linked perceptual class was formed in Phase 5.

Table 3

Frequency of errors occasioned by each cross-class probe during the initial test for the emergence of linked perceptual classes. Probe types are listed from left to right in their order of presentation.

		A′–B′									B′–A′								
		aa	ma	ba	am	mm	bm	ab	mb	bb	aa	ma	ba	am	mm	bm	ab	mb	bb
Participant	Class	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2898	1	0	0	0	0	0	0	0	0	0	0	**1**	**1**	0	0	0	**1**	0	0
2898	2	0	0	0	0	0	0	0	0	0	0	**1**	**1**	0	0	0	**1**	0	0
2897	1	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0	**1**	0	0	**1**
2911	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0	**1**
2896	1	0	0	0	**1**	**1**	**1**	0	0	0	0	**1**	0	0	**1**	0	0	**1**	0
2913	2	0	0	0	0	0	**1**	**1**	**1**	**1**	0	0	0	0	0	0	0	0	0
Total		**0**	**0**	**0**	**1**	**1**	**2**	**1**	**1**	**1**	**0**	**3**	**3**	**0**	**1**	**2**	**2**	**1**	**2**

Their data are presented in Figures 7 and 8. For each participant, the data from Phase 5 are presented in the lower panel. Since the probes that did not meet the mastery criterion in Phase 4 were the only ones presented in Phase 5, the lower panels show those probes only. For 4 of the 5 participants (2897, 2911, 2896, and 2913), the mastery criterion was satisfied for 17 of the 18 probes in one class during Phase 4. Between 2 and 6 of the probes in the other class did not satisfy the mastery criterion in Phase 4 but did so in Phase 5. In the case of the remaining participant (2898), 3 of the 18 probes in each class did not meet the mastery criterion in Phase 4 but all reached the criterion in Phase 5. These results demonstrated the delayed emergence of linked perceptual classes.

Errors during the delayed emergence of linked perceptual classes. Figures 7 and 8 showed that different types of errors occurred in Phase 4 during the delayed emergence of the linked perceptual classes. For Participants 2898, 2897, and 2911, there was only one type of error. For Participants 2898 and 2897, the errors involved the selection of the NEITHER comparison. For Participant 2911, they involved the selection of the comparisons from the perceptual class opposite that of the sample. For Participant 2896, all of the errors were of this latter type except for the bm and ba probes, where the NEITHER comparison was selected on one of the eight trials for each probe. The pattern of errors for Participant 2913 was the most complex, as indicated in Figure 8. Overall, the errors were essentially evenly distributed across the probe types (see Table 3).

Discrimination Training

In Phase 6 participants in Group Aa were trained to respond differentially to the A1a and A2a stimuli, and participants in Group Ba were trained to respond differentially to the B1a and B2a stimuli. Performance that satisfied the mastery criterion was achieved in an average of 3.0 and 1.9 blocks, respectively. Thus, the acquisition of both discriminations was rapid. Maintenance of the Aa and Ba discriminations during feedback reduction from 75% to 0% occurred in an average of 3.3 and 4.0 blocks, respectively. The results of a *t*-test confirmed that there was no significant difference in the number of blocks needed to initially acquire and then maintain the Aa or Ba discriminations in the absence of feedback, $t(13) = 0.52$, $p = 0.61$.

Generalization

Generalization of stimulus control to the members of the linked perceptual classes was assessed in Phase 7. The results are presented in Figure 9 for participants in Group Aa and in Figure 10 for participants in Group Ba. The data for each participant are presented in separate sections of each figure, bordered by the thick, solid lines. In each section, the top and bottom panels depict the generalization data for Linked Perceptual Classes 1 and 2, respectively. The abscissa lists the anchor, midpoint, and boundary stimuli for both of the linked perceptual classes, while the ordinate displays the percentage of trials on which the differential response (FR-3 or FR-7) occurred. The stimuli used in training are designated with the large black dot. In general,

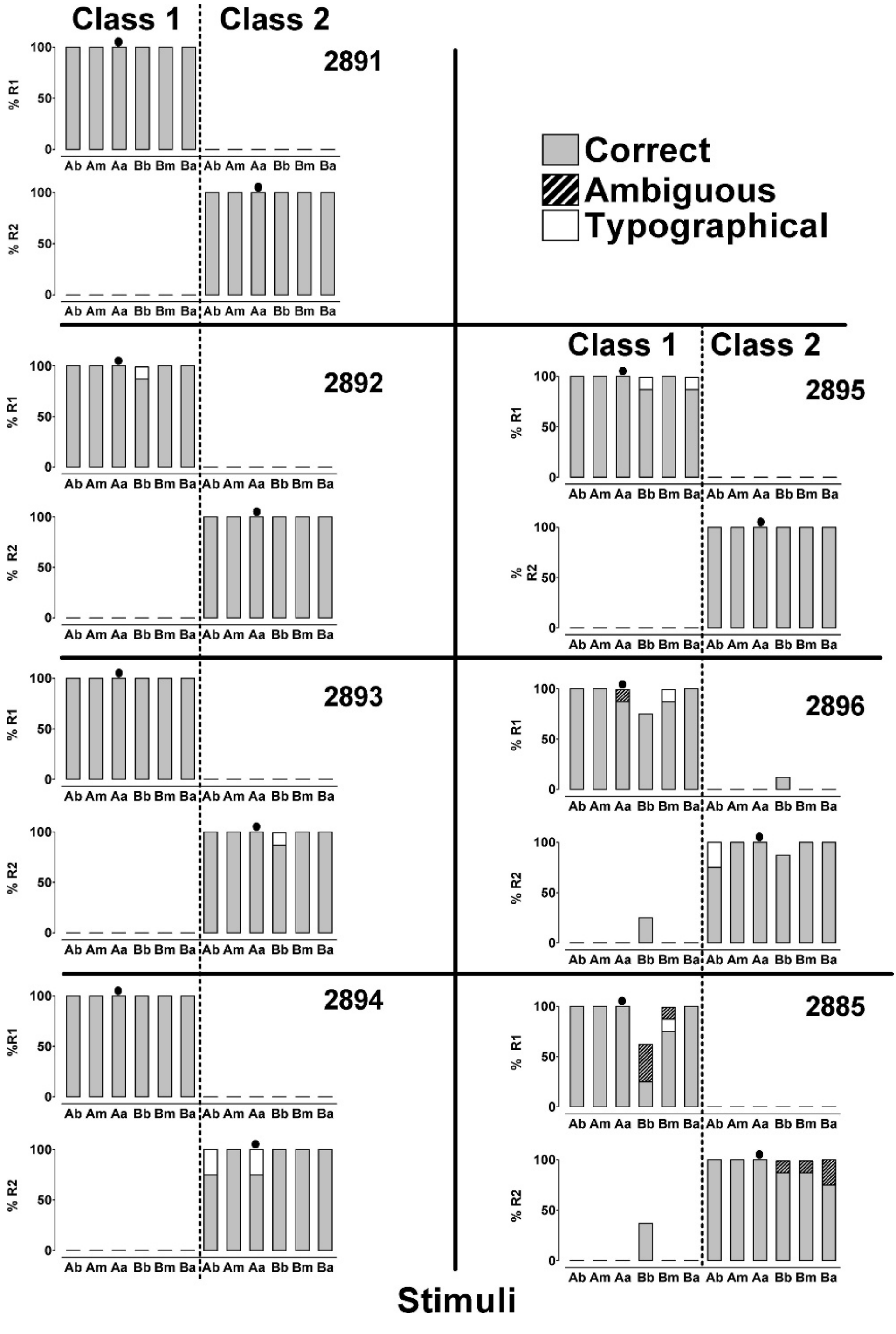

Fig. 9. Results from Phase 7 that depict the generalization of responding for participants in Group Aa. The data for each participant are presented in two panels. The upper panel indicates the likelihood of making the same response trained to the Aa stimulus in linked perceptual class 1 (during Phase 6) to the anchor, midpoint, and boundary stimuli in both linked perceptual classes. The lower panel indicates the likelihood of making the response trained to the Aa stimulus in linked perceptual class 2 (during Phase 6) to the anchor, midpoint, and boundary stimuli in both linked perceptual classes. The figure also shows the distribution of two types of errors that occurred during the generalization testing in Phase 7 (see text for details). There is no designation for the cross-class errors as they did not occur.

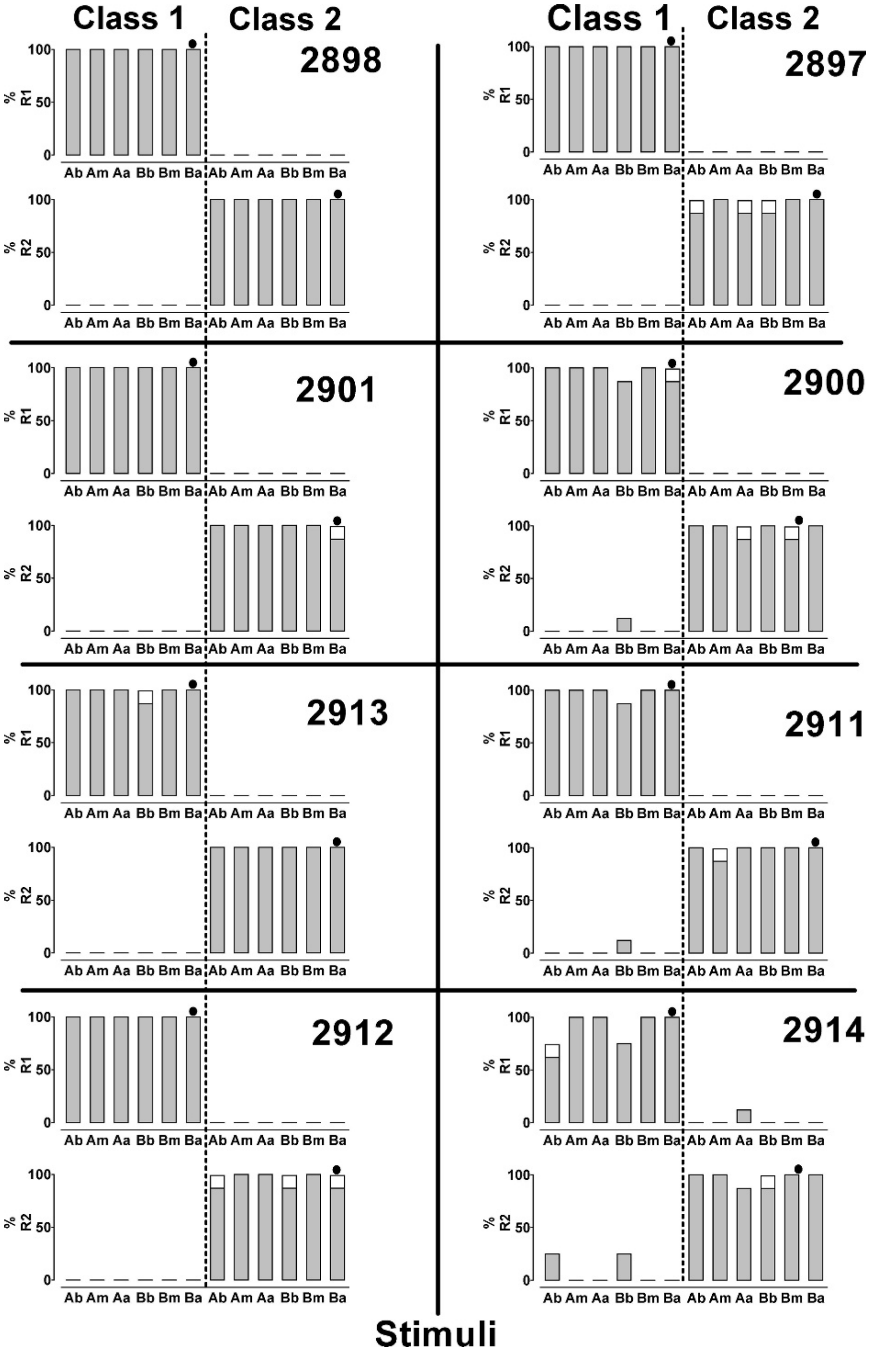

Fig. 10. Results from Phase 7 that depict the generalization of responding for participants in Group Ba. The data for each participant are presented in two panels. The upper panel indicates the likelihood of making the same response trained to the Ba stimulus in linked perceptual class 1 (during Phase 6) to the anchor, midpoint, and boundary stimuli in both linked perceptual classes. The lower panel indicates the likelihood of making the response trained to the Ba stimulus in linked perceptual class 2 (during Phase 6) to the anchor, midpoint, and boundary stimuli in both linked perceptual classes. The figure also shows the distribution of three types of errors that occurred during the generalization testing in Phase 7 (see text for details).

Table 4

Accuracy of response to each type of cross-class probe during the maintenance test for linked perceptual classes by group, participant, and class. Percentages less than 88 appear on a gray background.

			Test Type								
			A′–B′								
Grp.	Participant	Class	Aa	ma	ba	Am	Mm	bm	ab	mb	Bb
Aa	2891	1	100	100	100	100	75	100	100	100	100
		2	100	100	100	100	100	100	100	100	100
	2893	1	100	100	100	100	100	100	88	100	88
		2	88	100	100	100	100	100	100	100	88
	2896	1	100	100	100	100	100	100	100	100	88
		2	100	88	100	100	100	100	88	100	100
	2887	1	100	100	100	88	100	100	100	100	100
		2	100	100	100	100	100	100	100	100	88
	2892	1	100	100	100	100	100	100	100	100	100
		2	100	100	100	100	100	100	100	100	100
	2895	1	100	100	88	100	88	100	100	100	100
		2	100	100	100	88	100	100	100	100	100
Ba	2897	1	100	100	100	100	100	100	100	100	100
		2	100	100	100	100	100	100	100	100	100
	2900	1	100	100	100	100	100	75	88	100	100
		2	88	100	100	100	100	100	100	100	100
	2911	1	100	100	100	100	88	100	100	100	100
		2	100	100	100	100	100	100	100	100	88
	2913	1	100	100	100	100	100	100	100	100	100
		2	100	100	100	100	100	100	100	100	100
	2898	1	100	100	100	100	100	100	100	100	100
		2	100	100	100	100	100	100	100	100	100
	2901	1	100	100	100	100	88	100	88	100	100
		2	100	100	100	100	100	100	100	100	75
	2912	1	100	100	100	100	100	100	100	100	100
		2	100	100	100	100	100	100	100	100	100
	2914	1	100	100	100	100	100	100	100	88	100
		2	100	100	100	100	100	100	100	100	100

the data in Figures 9 and 10 show nearly complete generalization of responding among the stimuli in a linked perceptual class and essentially complete discrimination between the different linked perceptual classes. Thus, each linked perceptual class acted as a function-transfer network.

For Participant 2891 (see Figure 9), the FR-3 response trained to the Aa stimulus in Linked Perceptual Class 1 was evoked on all trials for the stimuli in that class and never occurred to the stimuli in Linked Perceptual Class 2. Likewise, the FR-7 response trained to the Aa stimulus in Linked Perceptual Class 2 was evoked on all trials for the stimuli in that class and never occurred to the stimuli in Linked Perceptual Class 1. These data demonstrate the strongest possible outcome.

In a few cases, however, weaker generalization occurred among the stimuli in a linked perceptual class (see the results for Participant 2885 in Figure 9) or there were weaker discriminations between the linked perceptual classes (see the results for Participant 2914 in Figure 10).

Generalization error analysis. Of the 1,440 stimuli presented in the generalization test in Phase 7, incorrect responses occurred to only 48 stimuli. For 13 of them, stimuli from one linked perceptual class evoked the response that had been trained to occur in the presence of a stimulus from the other linked perceptual class and were referred to as a *cross-class error.* Errors of this type were distributed among the stimuli in both classes and across participants.

Twenty-five other stimuli produced a number of presses of the J key that exceeded the respective FR requirement by one. These errors were referred to as ‘‘typographical’’ and were distributed across the stimuli in a perceptual class, across classes, and across participants. The remaining seven errors could

Table 4
(Extended)

Test Type								
B′–A′								
aa	ma	Ba	am	mm	bm	ab	mb	bb
100	100	100	100	100	100	100	100	100
100	100	88	100	100	100	88	100	100
100	100	88	100	100	88	100	88	100
100	100	100	100	100	88	88	100	100
100	100	100	100	88	100	100	100	100
100	100	100	88	100	88	100	100	100
100	100	100	100	100	100	100	88	88
100	100	100	100	100	88	100	100	75
100	100	100	88	100	100	100	100	100
100	100	100	100	100	100	100	100	100
100	100	100	100	100	88	100	100	100
100	100	100	100	100	100	100	100	100
100	100	100	100	100	100	100	100	100
100	100	100	100	100	100	100	100	100
100	100	100	100	100	100	88	100	100
100	100	100	100	100	100	100	100	100
100	100	100	100	100	88	100	100	100
100	100	100	100	100	100	100	100	88
100	100	100	100	100	100	100	100	100
100	100	100	100	100	100	100	100	100
100	100	100	100	100	100	100	100	88
100	100	100	100	100	100	100	100	100
100	100	100	100	100	100	88	100	100
100	100	100	100	100	100	100	100	100
100	100	100	100	100	88	100	100	100
100	100	100	100	100	100	88	100	100
100	100	100	88	100	88	100	100	100
100	100	100	100	100	100	100	100	100

not be classified as cross-class or typographical and were referred to as ‘‘ambiguous errors.’’ Figures 9 and 10 depict the incidence of the types of errors that were produced by the stimuli.

Maintenance of Linked Perceptual Classes

The experiment ended with an assessment of the maintenance of the linked perceptual classes following the generalization tests conducted in Phase 7. The results appear in Table 4. The maintenance test was a replication of the initial cross-class test used in Phase 2. The performances of the participants met the mastery criterion in almost all instances. For 4 participants (2891, 2887, 2900, and 2901), where performance failed to meet the criterion, the failure occurred for only one probe stimulus. These stimuli were different for each participant and, in each case, produced correct performance in 75% of the trials. For a 5th participant (2885), there were five probes where performance failed to satisfy the mastery criterion. In three cases, performance was at 75%; in the other two it was lower. In general, then, generalization testing did not disrupt the linked perceptual classes.

The emergence of linked perceptual classes was followed by generalization tests that evaluated whether each linked perceptual class also acted as a functional class. The results of those tests, however, demonstrated that such a development was not inevitable, as witnessed by the data presented in Figure 11 for Participant 2885. The panels in this figure depict the results of the generalization test and the maintenance test for each linked perceptual class. Different results were obtained in each class.

Linked Perceptual Class 1 was intact before and after the generalization test. The latter test, however, showed relatively poor general-

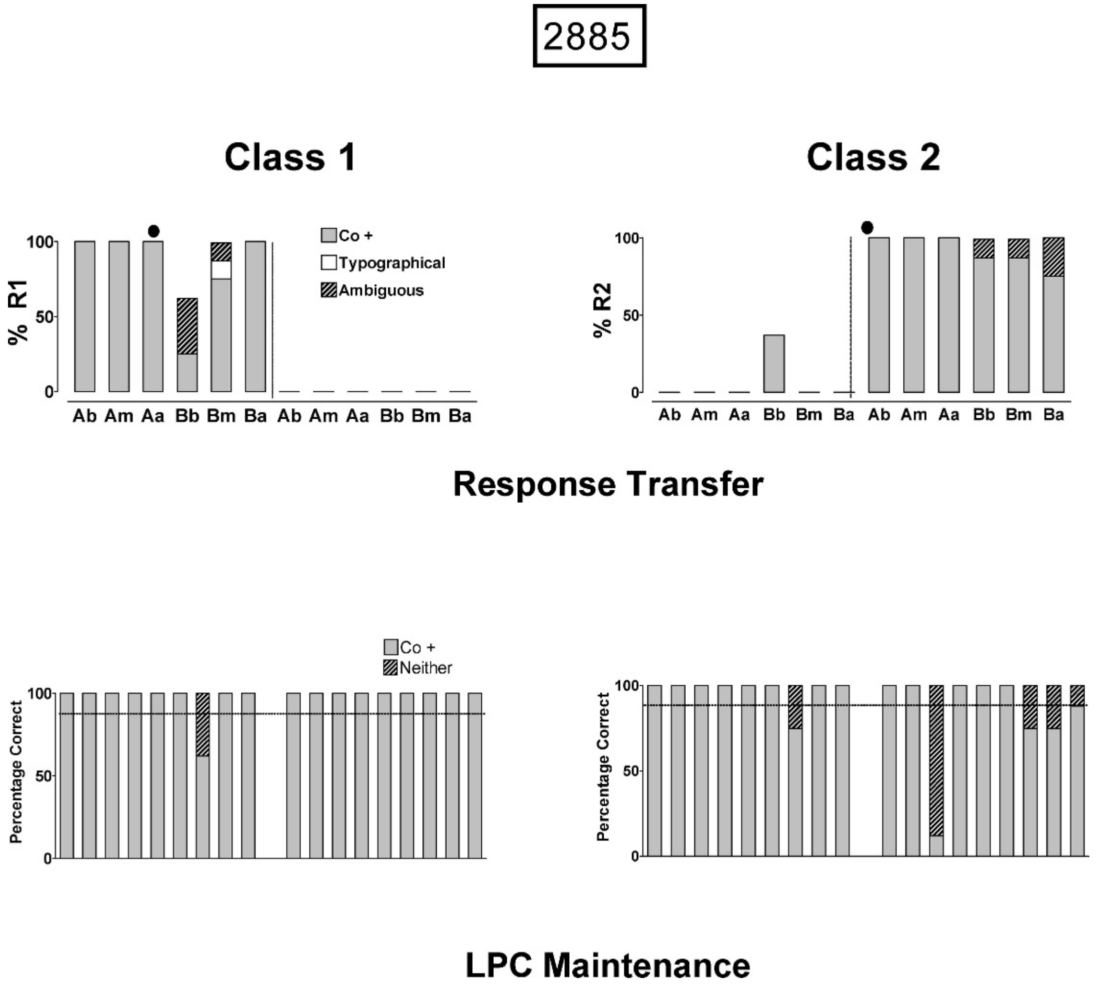

Fig. 11. Immediate emergence of linked perceptual classes and response transfer among the stimuli in each linked perceptual class for Participant 2885. The two upper panels are replicas of data shown in Figure 5 and show performances occasioned by cross- class probes during the initial test for class formation. The two lower panels are replicas of data shown in Figure 9 and show evocation of the response trained to one class member by the anchor, midpoint and boundary stimuli of both linked perceptual classes.

ization among stimuli in the class and poor discrimination between classes. In contrast, the generalization test for Linked Perceptual Class 2 showed strong generalization among stimuli in the class and strong discrimination between classes, but those performances were followed by a substantial breakdown of the linked perceptual class in Phase 8. Thus, the fact that a set of stimuli acts as a linked perceptual class does not necessarily imply that the stimuli will also act as a members of a functional class, and vice versa. The variables responsible for this dissociation of class and function transfer are yet to be determined.

DISCUSSION

Fields et al. (2007) explored the effects of different training conditions on the immediate emergence of linked perceptual classes. The establishment of Aa→Bb relations between the A′ and B′ perceptual classes was the most effective training condition; the condition resulted in the immediate emergence of linked perceptual classes in about 70% of participants. Fields et al. (2005) explored the effects of different testing procedures on the formation of linked perceptual classes. The 18/1-PRGM testing protocol was the most effective, producing class formation in 88% of participants without the need for reexposure to training. The present experiment combined the training and testing procedures previously identified as most effective. In cases where linked perceptual classes failed to form on the first exposure to the training procedure, participants were reexposed to the problematic cross-class probe stimuli. Two-thirds of the participants satisfied the mastery criterion for linked perceptual class formation during the initial testing phase (Phase 4). For the remainder, classes were formed in the subsequent reexposure phase (Phase 5). Thus, the combination of Aa→Bb training, the 18/1PRGM testing protocol, and reexposure to problematic test stimuli was successful in promoting the formation of linked perceptual classes by all participants.

While tracking the emergence of linked perceptual classes, Fields et al. (2007) found that errors usually were occasioned by the probes that were presented early in the sequence of test blocks. This finding suggested that linked perceptual classes emerged in a gradual rather than all-or-none fashion. That possibility was not evaluated, however, as participants were not reexposed to the error-producing probes at the end of the testing sequence. The present experiment included reexposure. In virtually all cases, reexposure to the probes that originally produced errors subsequently resulted in mastery-level responding. This finding confirmed that the formation of linked perceptual classes can occur gradually as well as immediately.

In the present experiment each of the 15 participants formed two linked perceptual classes. For 10 of the participants, both classes emerged on an immediate basis, four showed the immediate emergence of one class and the gradual emergence of the other, and one showed the gradual emergence of both classes. When individual linked perceptual classes were considered, 24 classes emerged on an immediate basis and 6 classes on a gradual basis. Additional research is needed to identify the factors that determine immediate and gradual emergence of linked perceptual classes.

The sample stimuli used in the discrimination training in Phase 6 were the anchor stimuli from the perceptual classes in the A Domain (Group Aa) or the anchor stimuli from the perceptual classes in the B Domain (Group Ba). Although the Aa and Ba stimuli occupied very different positions in the linked perceptual classes, generalization in each of them was strong across most of the stimuli in a class. Thus, linked perceptual classes act as function-transfer networks.

Function transfer is an important property of a stimulus class: individuals respond appropriately to new stimuli without direct training. Function-transfer networks include perceptual classes, equivalence classes, and minimally elaborated generalized equivalence classes. The present results support the inclusion of linked perceptual classes in that list.

In real-world settings, response and stimulus functions acquired by one class member generalize to the other members of the same class. Previous research with equivalence classes has shown these functions to include: (a) response topography (Barnes, Browne, Smeets, & Roche, 1995; Barnes-Holmes, Keane, & Barnes-Holmes, 2000; Fields, Newman, Adams, & Verhave, 1992; Rehfeldt & Hayes, 1998; Sidman & Cresson, 1973; Sidman et al., 1989); (b) discriminated avoidance behavior (Augustson & Dougher, 1997); (c) the acquisition and extinction of classically conditioned emotional behavior (Dougher, Augustson, Markham, Greenway, & Wulfert, 1994; Green, Sigurdardottir, & Saunders, 1991; Roche & Barnes, 1996, 1997); (d) approach and avoidance (Hayes, Kohlenberg, & Hayes, 1991); and (e) discriminative (S^d and S^{Δ}) functions (de Rose, McIlvane, Dube, Galpin, & Stoddard, 1988). In addition, generalization of function has also been demonstrated among the stimuli in minimally elaborated generalized equivalence classes (Belanich & Fields, 2003). The present study demonstrated the generalization of one of these functions, namely, the discriminative function acquired by one of the stimuli in a linked perceptual class. Future research will be needed to determine whether additional functions will transfer among the stimuli in a linked perceptual class. Finally, the results of the present study further strengthen accounts of the development of complex behavioral repertories that are based on the formation of complex stimulus classes (Critchfield & Fienup, 2008; Dymond & Rehfeldt, 2000; Fields & Moss, 2008; Hayes, et al., 2001; Leslie, 2002; Mackay & Fields, in press; Sidman, 1994, 2000; Tonneau, 2001).

REFERENCES

Adams, B. J., Fields, L., & Verhave, T. (1993). The effects of test order on the establishment and expansion of equivalence classes. *The Psychological Record, 43*, 85–105.

Augustson, E. M., & Dougher, M. J. (1997). The transfer of avoidance functions through stimulus equivalence classes. *The Journal of Behavior Therapy and Experimental Psychiatry, 28*, 181–191.

Bahrick, L. E., & Pickens, J. N. (1994). Amodal relations: The basis for intermodal perception and learning in infancy. In D. J. Lewkowicz, & R. Likliter (Eds.), *The development of intersensory perception: Comparative perspectives* (pp. 205–234). Englewood, NJ: Erlbaum.

Barnes, D., Browne, M., Smeets, P., & Roche, B. (1995). A transfer of functions and a conditional transfer of functions through equivalence relations in 3 to 6 year old children. *The Psychological Record, 45*, 405–430.

Barnes-Holmes, D., Keane, J., & Barnes-Holmes, Y. (2000). A derived transfer of emotive functions as a means of establishing differential preferences for soft drinks. *The Psychological Record, 50*, 493–512.

Belanich, J., & Fields, L. (1999). Tactual equivalence classes and cross modal transfer. *The Psychological Record, 49*, 75–91.

Belanich, J., & Fields, L. (2003). Generalized equivalence classes as response transfer networks. *The Psychological Record, 53*, 373–413.

Bentall, R. P., Jones, R. M., & Dickins, D. W. (1999). Errors and response latencies as a function of nodal distance in five-member equivalence classes. *The Psychological Record, 49*, 93–116.

Blough, D. S. (1978). Reaction times of pigeons on a wavelength discrimination task. *Journal of the Experimental Analysis of Behavior, 30*, 163–167.

Cook, R. G., & Katz, J. S. (1999). Dynamic object perception in pigeons. *Journal of Experimental Psychology: Animal Behavior Processes, 25*, 194–210.

Critchfield, T. S., & Fienup, D. (2008). Stimulus equivalence. In S. F. Davis, & W. Buskit (Eds.), *21st Century Psychology* (pp. 360–272). Thousand Oaks, CA: Sage.

Cumming, W. W., & Berryman, R. (1965). The complex discriminative operant: Studies of matching-to-sample and related problems. In D. I. Mostofsky (Ed.), *Stimulus generalization* (pp. 284–330). Stanford, CA: Stanford University Press.

de Rose, J. C., McIlvane, W. J., Dube, W. V., Galpin, V. C., & Stoddard, L. T. (1988). Emergent simple discrimination established by indirect relation to differential consequences. *Journal of the Experimental Analysis of Behavior, 50*, 1–20.

Dougher, M. J., Auguston, E., Markham, M. R., Greenway, D. E., & Wulfert, E. (1994). The transfer of respondent eliciting and extinction functions through stimulus equivalence classes. *Journal of the Experimental Analysis of Behavior, 62*, 331–351.

Dymond, S., & Rehfeldt, R. A. (2000). Understanding complex behavior: The transformation of stimulus function. *The Behavior Analyst, 23*, 239–254.

Fields, L., Adams, B. J., Brown, J. L., & Verhave, T. (1993). The generalization of emergent relations in equivalence classes: Stimulus substitutability. *The Psychological Record, 43*, 235–254.

Fields, L., Adams, B. J., Verhave, T., & Newman, S. (1990). The effects of nodality on the formation of equivalence classes. *Journal of the Experimental Analysis of Behavior, 53*, 345–358.

Fields, L., Fitzer, A., Shamoun, K., Matneja, P., Watanabe, M., & Tittelbach, D. (2005). The effect of test schedules on the formation of linked perceptual classes. *Journal of the Experimental Analysis of Behavior, 84*, 243–267.

Fields, L., Matneja, P., Varelas, A., & Belanich, J. (2003). Mutual selection and membership in open-ended classes: Variant-to-base and base-to-variant testing. *The Psychological Record, 53*, 287–311.

Fields, L., Matneja, P., Varelas, A., Belanich, J., Fitzer, A., & Shamoun, K. (2002). The formation of linked perceptual classes. *Journal of the Experimental Analysis of Behavior, 78*, 271–290.

Fields, L., & Moss, P. (2008). The formation of partially elaborated and fully elaborated generalized equivalence classes. *Journal of the Experimental Analysis of Behavior, 90*, 135–168.

Fields, L., Newman, S., Adams, B. J., & Verhave, T. (1992). The expansion of equivalence classes by simple discrimination training and stimulus fading. *The Psychological Record, 42*, 3–15.

Fields, L., & Reeve, K. F. (2000). Synthesizing equivalence classes and natural categories from perceptual and relational classes. In J. C. Leslie, & D. Blackman (Eds.), *Issues in experimental and applied analyses of human behavior*, Reno, NV: Context Press.

Fields, L., & Reeve, K. F. (2001). A methodological integration of generalized equivalence classes, natural categories, and cross-modal perception. *The Psychological Record, 51*, 67–88.

Fields, L., Reeve, K. F., Rosen, D., Varelas, A., Adams, B. J., Belanich, J., & Hobbie, S. A. (1997). Using the simultaneous protocol to study equivalence class formation: The facilitating effects of nodal number and size of previously established equivalence classes. *Journal of the Experimental Analysis of Behavior, 67*, 367–389.

Fields, L., Tittelbach, D., Shamoun, K., Fitzer, A., Watanabe, M., & Matneja, P. (2007). The effect of training variables on the formation of linked perceptual classes. *Journal of the Experimental Analysis of Behavior, I*, 97–119.

Fields, L., & Verhave, T. (1987). The structure of equivalence classes. *Journal of the Experimental Analysis of Behavior, 48*, 317–332.

Figuracion, D. (1998). *Morph (Version 2.5) Computer Software*. San Diego, CA: Gryphon Software Corp.

Flynn, B. M. (1943). Pitch discrimination: The form of the psychometric function and simple reaction time to liminal differences. *Archives of Psychology (Columbia University), 280*, 41.

Goldiamond, I. (1962). Perception. In A. J. Bachrach (Ed.), *Experimental Foundations of Clinical Psychology* (pp. 280–340). New York: Basic Books.

Green, G., Sigurdardottir, Z. G., & Saunders, R. R. (1991). The role of instructions in the transfer of ordinal functions through equivalence classes. *Journal of the Experimental Analysis of Behavior, 55*, 287–304.

Hayes, S. C., Barnes-Holmes, D., & Roche, R. (2001). *Relational frame theory: A post-Skinnerian account of human language and cognition*. New York: Plenum.

Hayes, S. C., Kohlenberg, B. S., & Hayes, L. (1991). The transfer of specific and general consequential functions through simple conditional equivalence relations. *Journal of the Experimental Analysis of Behavior, 56*, 119–137.

Jitsumori, M. (1993). Category discrimination of artificial polymorphous stimuli based on feature learning. *Journal of Experimental Psychology: Animal Behavior Processes, 3*, 244–254.

Jitsumori, M. (1994). Artificial polymorphous categories in humans and non-humans. In S. C. Hayes, L. J. Hayes, M. Sato, & K. Ono (Eds.), *Behavioral analysis of language and cognition* (pp. 91–106). Reno, NV: Context Press.

Keller, F. S., & Schoenfeld, W. N. (1950). *Principles of psychology.* New York: Appleton-Century-Crofts.

Lashley, K. S., & Wade, M. (1946). The Pavlovian theory of generalization. *Psychological Review, 53*, 72–87.

Lea, S. E. G. (1984). In what sense do pigeons learn concepts? In H. L. Roitblat, T. G. Bever, & H. S. Terrace (Eds.), *Animal cognition* (pp. 263–276). Hillsdale, NJ: Erlbaum.

Lea, S. E. G., & Harrison, S. N. (1978). Discrimination of polymorphous stimulus sets in pigeons. *Quarterly Journal of Experimental Psychology, 30*, 521–537.

Leslie, J. C. (2002). *Essential behavior analysis.* New York: Oxford University Press.

Mackay, H., & Fields, L. (In press). Syntax, grammatical transformation, and productivity: A synthesis of stimulus sequences, equivalence classes, and contextual control. In R. A. Rehfeldt, & Y. Barnes-Holmes (Eds.), *Derived relational responding: Applications for learners with autism and other developmental disabilities.* London: New Harbinger.

Mechner, F. (1994). *The revealed operant: A way to study the characteristics of individual occurrences of operant responses.* Cambridge MA: Cambridge Center for Behavioral Studies.

Reeve, K. F., & Fields, L. (2001). Perceptual classes established with forced-choice primary generalization tests and transfer of function. *Journal of the Experimental Analysis of Behavior, 76*, 95–114.

Rehfeldt, R. A., & Hayes, L. J. (1998). The operant-respondent distinction revisited: toward an understanding of stimulus equivalence. *The Psychological Record, 48*, 187–210.

Roche, B., & Barnes, D. (1996). Arbitrarily applicable relational responding and sexual categorization: A critical test of the derived difference relation. *The Psychological Record, 46*, 451–475.

Roche, B., & Barnes, D. (1997). A transformation of respondently conditioned stimulus function in accordance with arbitrarily applicable relations. *Journal of the Experimental Analysis of Behavior, 67*, 275–301.

Rosch, E. H., & Mervis, C. B. (1975). Family resemblances: Studies in the internal structure of categories. *Cognitive Psychology, 7*, 573–605.

Sidman, M. (1994). *Equivalence relations and behavior: A research story.* Boston: Authors Cooperative, Inc.

Sidman, M. (2000). Equivalence relations and the reinforcement contingency. *Journal of the Experimental Analysis of Behavior, 74*, 127–146.

Sidman, M., & Cresson, O., Jr. (1973). Reading and cross-modal transfer of stimulus equivalences in severe retardation. *American Journal of Mental Deficiency, 77*, 515–523.

Sidman, M., Wynne, C. K., Maguire, R. W., & Barnes, T. (1989). Functional classes and equivalence relations. *Journal of the Experimental Analysis of Behavior, 52*, 261–274.

Spencer, T. J., & Chase, P. N. (1996). Speed analysis of stimulus equivalence. *Journal of the Experimental Analysis of Behavior, 65*, 643–659.

Tonneau, F. (2001). Equivalence relations: A critical analysis. *European Journal of Behavior Analysis, 2*, 1–33.

Wasserman, E. A., Kiedinger, R. E., & Bhatt, R. S. (1988). Conceptual behavior in pigeons: Categorization of both familiar and novel examples from four classes of natural and artificial stimuli. *Journal of Experimental Psychology: Animal Behavior Processes, 3*, 235–246.

Watanabe, S. (2001). Van Gogh, Chagall and pigeons: Picture discrimination in pigeons and humans. *Animal Cognition, 4*, 147–151.

Wirth, O., & Chase, P. N. (2002). Stability of functional equivalence and stimulus equivalence: Effects of baseline reversals. *Journal of the Experimental Analysis of Behavior, 77*, 29–47.

Received: November 28, 2006
Final Acceptance: December 8, 2008