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THE CONTEXTUALLY CONTROLLED, FEATURE-MEDIATED CLASSIFICATION OF SYMBOLS

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The classification of names of people or objects based on the features acquired by the names and the sorting instructions provided is a commonplace occurrence. For example, given the names Renoir, Pollock, James and Voltaire the average adult would be able to classify them differentially based on the instruction to classify them based on vocation or nationality. In general, such a repertoire reflects the reclassification of symbols (i.e, the names of individuals) in terms of contextual cues (instructions to sort by vocation or nationality) and the features acquired by the symbols (the specific nationalities and vocations). The present experiment studied this phenomenon with the use of arbitrary stimuli that did not have clear preexperimental associations. Two of 4 participants classified the symbols into different equivalence classes based on the prevailing contextual cues and the features that had been acquired by the symbols. Using an ABA reversal design we then demonstrated that 1 participant classified the symbols in accordance with the contextual cues and acquired features when present, but not in the absence of the contextual cues. A 3rd participant showed symbol classification that differed from that predicted by the procedures, and the 4th classified the symbols based on one set of features but not on context. These data describe one set of conditions that could account for the establishment of complex classification repertoires that occur in natural settings.

Key words: stimulus equivalence, contextual control, hierarchical classification, acquired features of symbols, keyboard responding, college students

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A typically developing child will sort or cluster a set of toys into different groups based on color, size, weight or shape depending on the instruction that precedes the request for sorting. When asked to group by color, all of the toys of the same color will be clustered together but the toys in a group will vary in terms of size, weight and shape. Corresponding outcomes would occur when asked to group by size, weight or by shape. Each cluster of toys can be viewed as a stimulus class, the members of which share a common defining feature (i.e.: color, size, weight or shape). Depending on the instruction, each toy serves as a member of four different classes. For example, the toy that is red, large, heavy, and long serves as a member of the class of red toys, large toys, heavy toys, or long toys. Indeed, the clustering of the toys into different classes reflects control of behavior by (a) the prevailing instruction which specifies the category to be used for classification (color, size, weight or shape), in combination with (b) the particular features of each toy (e.g., red, 4 inches long, 4 ounces, or pyramidal). The instructions, then, are acting as contextual cues that are discriminative for the classification of the objects based on one of four features of each object. The classification of objects, events or symbols into different sets based on context and the properties or features acquired by the objects, events or symbols characterizes a broad range of human activity. This phenomenon has been referred to as *contextually controlled classification* (Bush, Sidman & deRose, 1989) or *hierarchical classification* (Barsalou, Simmons, Barbey & Wilson, 2003).

In the previous example, the features that control class assignment are present at the time of testing. Classification, however, can also occur when the features that control class assignment are not present at the time of testing. This can be illustrated with baseball cards. The front of each card has a picture of a baseball player. The back of each card lists many characteristics of that player such as the position played, batting average, and the city in which the team resides. Without looking at the back of the card, an avid fan can readily sort the cards based on any of the categories mentioned above (the position played, the batting average, the city in which the team resides), and the particular values in the

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indicated category (e.g., short stop, Philadelphia). In this example, the particular features used for class assignment and reassignment are not visible at the time of classification. Another example of hierarchical classification in the absence of acquired features involves the performances required of a typical college student enrolled in an Art History course. Here, pictures of famous paintings and other works of art are categorized by artist, style, country of origin, time period, and production media, etc. To summarize, a stimulus can have many defining features and a set of stimuli can be classified into clusters that share one feature under some conditions and share other features under other conditions. Further, the features that are being attended to (i.e. that are exerting selective stimulus control) and lead to effective clustering, need not be present during the classification tests.

To date, little research has been conducted to identify the training histories and stimulus control repertories needed to induce behavior indicative of hierarchical classification of entire sets of stimuli based on properties previously acquired by those stimuli. A small number of experiments, however, have explored highly restricted forms of hierarchical classification (Bush, et al., 1989; Dymond & Barnes, 1995; Gatch & Osborne, 1989; Gomez, Barnes-Holmes & Luciano, 2002; Griffee & Dougher, 2002; Lynch & Green, 1991; Rehfeldt, 2003; Whelan & Barnes-Holmes, 2004). All of these studies assessed the switching of a single stimulus to different equivalence classes based on the presence of different contextual cues. The switching of class membership in these studies was based on discrimination-reversal contingencies that prevailed in the presence of the contextual cues rather than on some acquired feature of the stimuli in question. In another study, Meehan and Fields (1995) showed that contextual cues could control the assignment of single stimuli to different classes based on the physical features of the stimuli (number, letter). Thus, the sorting was conducted with stimuli whose properties were present at the time of the sorting. That study, however, did not evaluate either reclassification of all stimuli in a set to different equivalence classes, or the classification of stimuli based on features not present at the time of the classification. To summarize, none of these experiments explored how contextual stimuli come to control the classification of entire sets of symbols into different equivalence classes based on the features acquired by the symbols.

The analysis of the phenomenon will be illustrated using an elaboration of an example presented by Bush et al. (1989) as depicted in Figure 1. Assume that the objects or pictures in the previous examples are replaced by words that are the surnames of nine individuals: Pollock, Renoir, Bosch, James, Voltaire, Goethe, Gershwin, Debussy and Beethoven. The names can be referred to as *symbols.* In addition, the name of each individual is correlated with two categories: the individual's nationality and the individual's vocation. The labels ''nationality'' and ''vocation'' will be referred to as *category names.* For a given category, the individual has a particular nationality (American, German, or French), and a particular vocation (composer, painter, or writer). Each of the particular nationalities and vocations will be referred to as an *acquired feature.* Thus, each symbol will be associated with a unique combination of a specific nationality-based feature and a vocation-based feature.

Because each of the nine symbols is associated with a unique combination of acquired features, when asked to classify them based on nationality, an individual ought to cluster Pollock, James and Gershwin because all are American; Renoir, Voltaire and Debussy because all are French; and Bosch, Goethe and Beethoven because all are German. In contrast, when asked to classify the nine symbols based on vocation, an individual would cluster Pollock, Renoir and Bosch because all are painters; James, Voltaire and Goethe because all are writers; and Gershwin, Debussy and Beethoven because all are composers.

Because the three names in a cluster are perceptually distinct and are treated in the same manner, they would be functioning as members of an equivalence class (Fields & Verhave, 1987; Sidman, 1971; 1994; 2004). Further, each symbol may function as a member of two separate equivalence classes: a vocation-based and a nationality-based equivalence class. For example, when sorted by vocation, the symbol Pollock would be clustered with the symbols Renoir and Bosch because of their prior linkages to the same vocation feature: painter. In contrast, when sorted by nationality, Pollock would be clus-

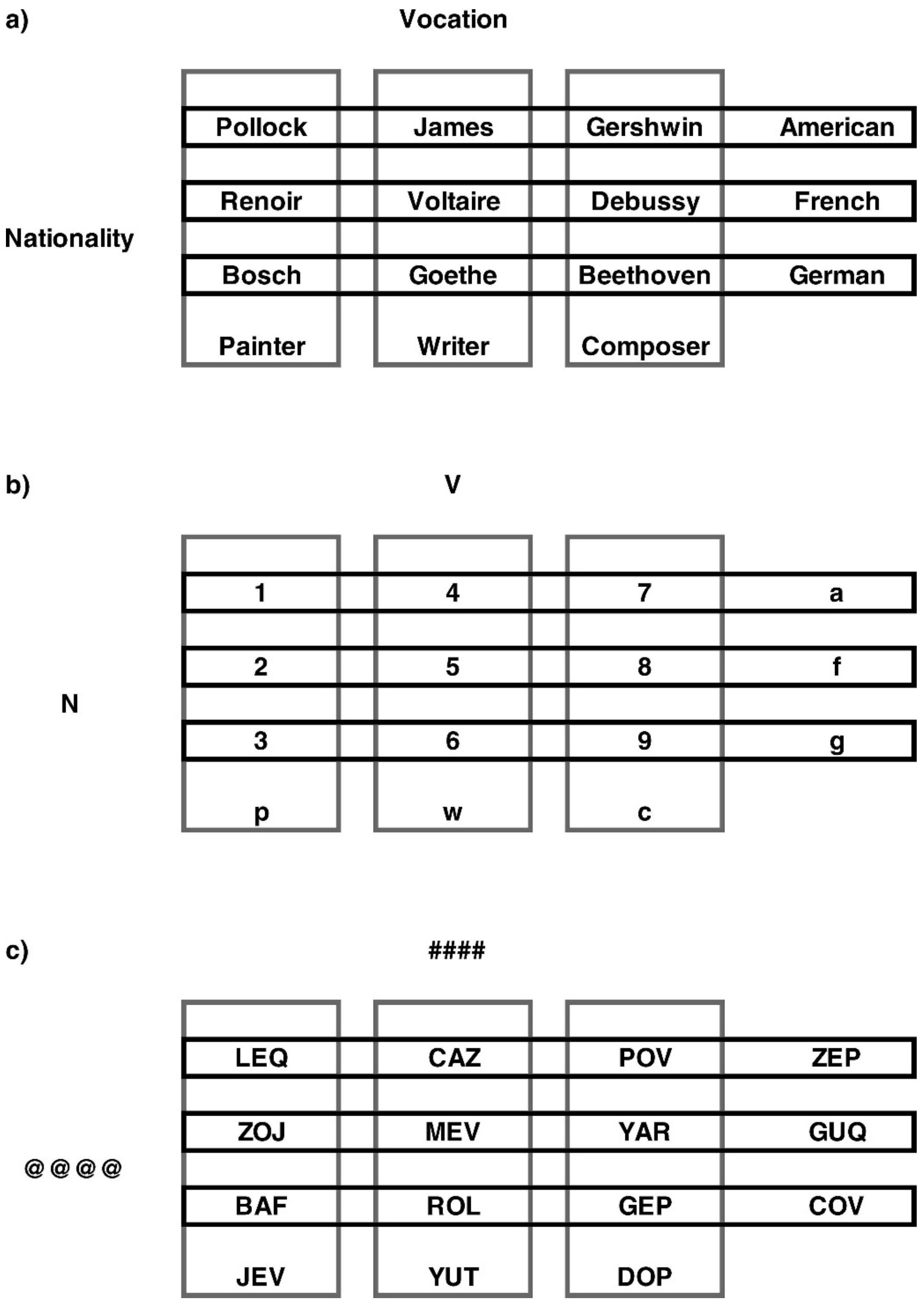

Fig. 1. Six potential equivalence classes based on either ''vocation'' or ''nationality'' illustrated with (a) metaphorical names, (b) symbolic representation, and (c) the actual stimuli used in the experiment. Classes based on ''vocation'' are ringed in gray and classes based on ''nationality'' are ringed in black.

tered with James and Gershwin because of their prior linkages to the same nationality: American. The assignment of Pollock to one of the two equivalence classes, then, is controlled by the category presented at the time of classification (a contextual cue), and the vocation- or nationality-based features acquired by the symbols but not present at the time of sorting. The same can be said for each of the nine names. Therefore, the nine names would give rise to six different equivalence classes, the members of which are defined by the cellular entries in each row and column of Figure 1a. The goal of the present experiment is to describe a set of training and testing procedures that induce the classification of symbols into different equivalence classes based on contextual cues (i.e., category names) and the particular category-based features acquired by the symbols.

METHOD

Participants

Eleven undergraduate students were recruited through flyers posted on the campus of Queens College in Flushing New York. Participants were paid $10 per hr for their participation. The duration of the experiment ranged from 6 to 8.5 hr and was completed within three sessions over a maximum of 5 consecutive days.

Apparatus

Hardware and software. An MS-DOS compatible microcomputer was the experimental platform. Each participant was seated at a table in a cubicle that held the computer, a monochrome monitor, and a keyboard. During all phases of the experiment, responses were made by pressing specified keys on the keyboard. All stimuli in the experiment occupied 2-inch × 2-inch spaces on the monitor. All aspects of the experiment were controlled by a customized software package, which also collected data on a trial-by-trial basis.

Stimuli. Figure 1c illustrates the stimuli used in the present experiment. Figure 1a identifies the metaphorical names utilized that correspond to the combined Vocation- and Nationality-based features. Figure 1b presents these stimuli using numbers and letters. The numbers and letters are used as proxies to denote the symbols, features and category names. These proxies will be used to depict the trained and derived relations used in the experiment. For purposes of explication, the various representations of the stimuli will be used interchangeably. The symbols or their proxies are represented by Arabic numerals (1 through 9). The particular features or their proxies were represented with lower case letters for the three nationalities, American, French, and German (a, f, and g), and three other letters for the three vocations, composer, writer and painter (c, w, and p). Finally, the two category names corresponding to Nationality and Vocation are represented by upper case letters (N and V). Figure 1c illustrates the nonsense syllables used as the symbols and acquired features, and the glyph strings used as category names.

Procedure

Trial structure, contingencies, and responses within a trial. All training and testing trials were conducted using a two-choice matching-to-sample (MTS) procedure. Each trial began when the phrase ''Press ENTER to begin'' appeared on the screen. Pressing the ENTER key replaced this message with the sample stimulus (Sa). Pressing the SPACE BAR in the presence of a sample produced the positive comparison (Co+) and the negative comparison (Co−). The sample and comparison stimuli were presented in the array of an isosceles triangle with the sample at the vertex and the comparisons at the ends of the base. Participants made their selection by pressing the 1 key for the comparison located on the left or 2 key for the comparison located on the right. Any selection resulted in the end of the trial and all responses produced a written feedback message in the center of the screen.

On trials in which differential feedback was scheduled, if the Co+ was selected, the word RIGHT appeared on the screen until the participant pressed the R key on the computer keypad. If the Co− was selected, the word WRONG appeared on the screen until the participant pressed the W key on the computer keyboard. On trials in which nondifferential feedback was scheduled, either selection produced the letter E on the screen until the participant pressed the E key. Pressing the R, W, or E key cleared the screen and initiated the next trial. The E key was selected because it is between the R and W keys on the keyboard (Fields, Adams, Brown & Verhave, 1993).

Acquisition and maintenance of trained relations. When a training block was introduced, selection of either comparison was followed by differential feedback. Initially, all conditional discrimination-training trials were conducted with 100% feedback. Each training block was repeated until the participant achieved the mastery criterion. The mastery criterion for a block was determined by the number of trials within the block but was always at least 95% correct. Upon achieving the mastery criterion, differential feedback was reduced in successive blocks of trials from 100%, to 75%, to 25%, and finally to 0% provided that the mastery criterion was maintained at each level. When informative feedback was less than 100%, if the mastery criterion was not met within four blocks, the participant returned to the previous level of feedback until the mastery criterion was met before returning to the failed block.

Design

The experiment was conducted in nine phases. Phase 1 was keyboard familiarization training in which participants learned how to respond to the stimuli presented in each trial. Phase 2 involved the establishment of two feature-category sets. One set involved the establishment of relations between three nationality-based features and the nationality-based category label (a,f,g→N). The other set involved the establishment of relations between three vocation-based features and the vocation based category label (c,p,w→V). Phase 3 involved the establishment of the three vocation-based symbol-feature equivalence classes (123-p, 456-w, and 789-c), where each contained three symbols and one vocation-based feature. Phase 4 involved the establishment of three nationality-based symbol-feature equivalence classes (147-a, 258-f, and 369-g) where each contained three symbols and one nationality-based feature. Phases 5 and 6 were symbol–dual feature and dual feature–symbol tests that assessed the emergence of relations between each symbol and the unique pair of features that had been trained separately to it. Phase 7 involved the reinstatement of the feature-category name relations that had been established in Phase 2. Phase 8 was a classification test that assessed whether contextual cues or category labels would maintain separable equivalence classes even though each symbol was linked by common acquired features to all others. Finally, in Phase 9, a within-participant reversal design was conducted to assess control by vocation and nationality category names of the separable equivalence classes even though each symbol was linked by common acquired features to all others.

Phase 1: Keyboard familiarization. During keyboard familiarization training, common English words were used as samples and comparisons and participants were trained to make the appropriate within-trial keyboard responses by the serial deletion of on-screen instructional prompts. Participants were initially provided with the following instructions:

> Thank you for volunteering to be a subject 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 contains three CUES. These will be common words or three-letter nonsense words such as ZEQ or WUV.
>
> ***
>
> YOUR TASK IS TO DISCOVER WHICH CUES GO TOGETHER.
>
> ***
>
> Initially there will also be INSTRUCTIONS that tell you how to respond to the cues, as well as LABELS that will help you identify the cues on the screen. The labels and the instructions, which tell you which KEYS to press, will slowly disappear. Your task will be to RESPOND CORRECTLY to the CUES and the INSTRUCTIONS by pressing a key on the computer's keyboard.
>
> ***
>
> The experiment is conducted in phases. SOMETIMES you will see information on the screen that tells you how you did in the previous phase. If you want to take a break, you may do so at any time by calling the experimenter.

After the subject read the instructions, the experimenter answered any questions by repeating the relevant portion of the above mentioned instructions, and then left the room.

Phase 2: Feature-category name sets. Comparison-as-node training (Saunders, Saunders, Williams, & Spradlin, 1993) was used to establish relations between the three voca-

Table 1

Trial configurations in each training block (T) and testing block (M) used to establish feature-category relations.

Block	Trial Type	Symbolic Sa	Symbolic Co+	Symbolic Co−	Metaphorical Sa	Metaphorical Co+	Metaphorical Co−
T1	Training	p	V	N	Painter	Vocation	Nationality
		a	N	V	American	Nationality	Vocation
T2	Training	w	V	N	Writer	Vocation	Nationality
		f	N	V	French	Nationality	Vocation
M2	Testing	p	V	N	Painter	Vocation	Nationality
		w	V	N	Writer	Vocation	Nationality
		a	N	V	American	Nationality	Vocation
		f	N	V	French	Nationality	Vocation
T3	Training	c	V	N	Composer	Vocation	Nationality
		g	N	V	German	Nationality	Vocation
M3	Testing	p	V	N	Painter	Vocation	Nationality
		w	V	N	Writer	Vocation	Nationality
		c	V	N	Composer	Vocation	Nationality
		a	N	V	American	Nationality	Vocation
		f	N	V	French	Nationality	Vocation
		g	N	V	German	Nationality	Vocation

Note. Blocks were presented as ordered in the left column. Subsequent columns indicate the stimuli used in each block. Stimuli are shown by the symbolic representations and metaphorical representations, respectively. Details regarding the randomization of trials within each block are provided in the text.

tion-based feature stimuli represented by p, w, and c and the category name represented by V, as well as the three nationality-based feature stimuli a, f and g and the category name represented by N. The vocation- and nationality-based feature stimuli were presented as samples along with the category names V and N as a pair of comparison stimuli. On trials with vocation-based features as samples, the category names *vocation* and *nationality* served as the Co+ and Co−, respectively. On trials with a nationality-based features as samples, the category names *nationality* and *vocation* served as the Co+ and Co−, respectively. These relations were established in a serial manner over three phases of training (T1, T2, and T3) and two phases of testing (M2 and M3) assessed in the absence of informative feedback. Table 1 lists the symbolic and metaphorical representations of the stimuli used during each phase.

Phase 3: Vocation-based equivalence classes. Phase 3 involved the establishment of three 4-member vocation-based symbol-feature equivalence classes with a comparison-as-node training structure and a simple-to-complex training and testing protocol (Adams, Fields, & Verhave, 1993). Each class was composed of three symbols and one feature from the V category. Metaphorically, these classes consisted of Pollock–Renoir–Bosch–painter, James–Voltaire–Goethe–writer, and Gershwin–Debussy–Beethoven–composer. Symbolically, these classes are represented as 123p, 456w, and 789c. These classes are illustrated metaphorically and symbolically in the columns of Figure 1a and 1b, respectively. The actual stimuli used to represent these classes are shown in the columns of Figure 1c.

Establishment of 3-member classes. Table 2 details the procedures used to establish the vocation-based equivalence classes. Training began with the establishment of the conditional discriminations (Block T1), Pollock→painter (1→p), James→writer (4→w), and Gershwin→composer (7→c). Once acquired, a symmetry test (Block S1) was conducted to assess the reversibility of the function of the stimuli in the trained relations. Thus, the features (p, w, c) were presented as samples along with the names (1 through 9) as the set of comparison stimuli. All symmetry probes were randomized within a single block and presented with uninformative feedback. The test block was repeated up to three times or until mastery was attained, that is, 100% correct. Thereafter, conditional discrimination training was used to establish the Renoir→painter (2→p), Voltaire→writer (5→w) and Debussy→composer (8→c) relations

Table 2

Training and testing trials used to establish three vocation-based equivalence classes.

	Equivalence Class								
	123p			456w			789c		
BLK	Sa	Co+	Co−	Sa	Co+	Co−	Sa	Co+	Co−
T1	1	p	w	4	w	p	7	c	p
			c			c			w
S1	p	1	4	w	4	1	c	7	1
			7			7			4
T2	2	p	w	5	w	p	8	c	p
			c			c			w
S2	p	2	5	w	5	2	c	8	2
			8			8			5
MS1	**COMBINES ALL TRIALS INCLUDED IN T1, T2, S1 & S2**								
E1	1	2	5	4	5	2	7	8	2
			8			8			5
	2	1	4	5	4	1	8	7	1
			7			7			4
M1	**COMBINES T1, T2, S1, S2 & E1: COMBINED TEST FOR 3M CLASSES**								
T3	3	p	w	6	w	p	9	c	p
			c			c			w
S3	p	3	6	w	6	3	c	9	3
			9			9			6
MS2	**COMBINES T1, T2, T3, S1, S2 & S3**								
E2	1	3	6	4	6	3	7	9	3
			9			9			6
	2	3	6	5	6	3	8	9	3
			9			9			6
	3	1	4	6	4	1	9	7	1
			7			7			4
	3	2	5	6	5	2	9	8	2
			8			8			5
M2	**COMBINES ALL TRIALS INCLUDED IN T1–T3, S1–S3 & E1–E2**								

Note. The far left column (BLK) lists the designation assigned to the block and is described in the text. Subsequent columns indicate the sample and comparison pairs used during the blocks that correspond to the different vocation-based equivalence classes. The absence of a Sa or Co+ in a row indicates that the Sa and Co+ for that trial were identical to those presented in the preceding line above. Each trial within a block was presented four times regardless of block type or, within training trials, during feedback reduction.

(Block T2) and was followed with tests for the symmetrical properties of the stimuli in these baseline relations (Block S2). After demonstrating symmetry for this second set of relations, a mixed block (Block MS1) assessed the maintenance of all of the previously trained and tested relations. Next, participants were tested for the emergence of equivalence relations (Block E1) among the symbols within a class (i.e. Pollock, Renoir, and Bosch) that had become related to each other through linkage to the nodal feature (i.e. painter). During this test block a total of 96 novel equivalence probes was presented. These probes were presented twice during a test block such that each test block consisted of 192 trials. The test block was presented twice such that each probe was presented to the participant four times. During these equivalence tests the mastery criterion was defined as maximum of two errors within a block or at least 95% correct.

After passing the equivalence tests, all of the previously acquired baseline and derived relations were combined in a series of mixed test blocks that consisted of 144 unique trials (M1). Each trial configuration was presented two times within a test block and the block was repeated two times such that each probe type was presented four times. The mastery criterion for this mixed testing was defined as a maximum of four errors or at least 95% correct.

Expansion of class size from three to four members. Upon satisfactory completion of the mixed test block, the third and final set of conditional discriminations was established. These included the relations Bosch→painter (3→p), Goethe→writer (6→w), and Beethoven→composer (9→c), (Block T3). Following the establishment of these relations the symmetrical properties of these trained relations were presented (Block S3) and upon demonstration of the symmetrical relations a mixed symmetry block (Block MS2) that included all previously trained baseline conditional discriminations, and their symmetrical relations, was assessed. Following the mixed symmetry block equivalence among all relations were assessed in a mixed block (Block E2) containing 192 novel trial configurations which were presented over three test blocks. Following the demonstration that all baseline and equivalence relations were intact, all trained and emergent relations were assessed in three final mixed test blocks (Block M2). Training and testing, then, were used to form the vocation-based equivalence classes 123-p, 456-w and 789-w. Upon the successful completion of these training and testing blocks, training on the nationality-based equivalence classes was initiated.

It should be noted that the equivalence probes used to track the formation of the vocation-based equivalence classes (shown in Table 2) contained only some of the Co−s that could have been used in combination with a given Sa/Co+ pair. For example, on an equivalence probe in which Renoir was presented as the sample and Pollock was presented as the Co+, six other symbols could have been used as the Co−: James, Voltaire, Debussy, Gershwin, Beethoven, or Goethe. In these trials however, only four of the six symbols were used as a Co−, each on different trials: James, Gershwin, Beethoven, and Goethe. The remaining symbols, Debussy and Voltaire, were not used as Co−s on trials where Renoir served as the sample because we did not want to disrupt performance on later nationality-based trials when those stimuli would serve as Co+s.

Phase 4: Nationality-based equivalence classes. Phase 4 involved the establishment of three 4-member equivalence classes, each of which were composed of the names of three individuals and their nationality. Metaphorically, these classes consisted of American–Pollock–James–Gershwin, French–Renoir–Voltaire–Debussy, and German–Bosch–Goethe–Beethoven. Symbolically, these classes are represented as 147-a, 258-f and 369-g. These classes are illustrated metaphorically and symbolically in the rows of Figure 1a and 1b, respectively. The actual stimuli used during the experiment are shown in the rows of Figure 1c. The training and testing trials utilized for the establishment of these classes were structured in the same way as those used for the establishment of the vocation-based classes and are illustrated in Table 3.

Phase 5: Symbol–dual feature tests. During the formation of the vocation- and nationality-based equivalence classes, each symbol became related to one acquired feature in a domain and in isolation. The symbol–dual feature tests assessed the emergence of relations between each symbol and the concurrently presented pair of vocation- and nationality-based features with which it had become related during prior class formation. The stimuli presented in each test trial are illustrated in Table 4.

During the symbol–dual feature tests, each symbol was presented as a sample stimulus along with combinations of vocations and nationalities as positive and negative comparisons. Although only one positive comparison would be presented on any trial, one of three negative comparison types was presented and these varied across trials. The Co+ on any given trial consisted of a compound stimulus that contained the vocation-based feature associated with the sample as well as the nationality-based feature associated with the sample. For example, on a trial in which the symbol for Pollock served as sample, the Co+ consisted of the features corresponding to American along with Painter because Pollock's nationality was American, and his vocation was that of a painter.

One of the Co−s contained neither of the features that were related to the symbols used in the trial (e.g., French composer). Another Co− contained the nationality-based feature that was the same as that acquired by the symbols used as the sample stimulus, and a vocation-based feature that differed from that acquired by the symbol used as the sample stimulus (e.g., American composer). The last Co− contained the vocation-based feature that was the same as that acquired by the symbols used as the sample stimulus, and a nationality-based feature that differed from that acquired by the symbol used as the sample stimulus (e.g., French painter). These tests were anal-

Table 3

Training and testing trials used to establish three nationality-based equivalence classes.

	Equivalence Class								
	147a			258f			369g		
BLK	Sa	Co+	Co−	Sa	Co+	Co−	Sa	Co+	Co−
T1	1	a	f	2	f	a	3	g	a
			g			g			f
S1	a	1	2	f	2	1	g	3	1
			3			3			2
T2	4	a	f	5	f	a	6	g	a
			g			g			f
S2	a	4	5	f	5	4	g	6	4
			6			6			5
MS1	**COMBINES ALL TRIALS INCLUDED IN T1, T2, S1 & S2**								
E1	1	4	5	2	5	4	3	6	4
			6			6			5
	4	1	2	5	2	1	6	3	1
			3			3			2
M1	**COMBINES ALL TRIALS INCLUDED IN T1, T2, S1, S2 & E1**								
T3	7	a	f	8	f	a	9	g	a
			g			g			f
S3	a	7	8	f	8	7	g	9	7
			9			9			8
MS2	**COMBINES ALL TRIALS INCLUDED IN T1, T2, T3, S1, S2 & S3**								
E2	1	7	8	2	8	7	3	9	7
			9			9			8
	7	1	2	8	2	1	9	3	1
			3			3			2
	4	7	8	5	8	7	6	9	7
			9			9			8
	7	4	5	8	5	4	9	6	4
			6			6			5
M2	**COMBINES ALL TRIALS INCLUDED IN T1–T3, S1–S3 & E1–E2**								

Note. The far left column (BLK) lists the designation assigned to the block and is described in the text. Subsequent columns indicate the sample and comparison pairs used during the blocks that correspond to the different vocation-based equivalence classes. No Sa or Co+ listed in a row indicates that the Sa and Co+ were identical to those presented in the preceding row. Each trial within a block was presented four times regardless of block type or, within training trials, during feedback reduction.

ogous to asking the participant to indicate the characteristics of the individual being named. Correct performances indicated that each symbol had become related to the combination of features with which it had become associated on a separate basis in prior training.

On these trials, the sample and comparison stimuli were presented in the array of an isosceles triangle with the sample at the vertex and the comparisons at the ends of the base. The comparison stimuli were presented as compound stimuli with a ''/'' between the two stimuli such that on a trial in which Renoir was presented as a sample, the positive comparison was French/painter. The negative comparison varied across trials but was presented in the same format (i.e. American/writer).

Phase 6: Dual feature–symbol tests. Following the demonstration that each symbol had acquired the appropriate feature relations, the symmetrical properties of these relations were evaluated with dual feature–symbol tests. During this phase, sample stimuli consisted of all possible combinations of features, (vocation and nationality), with the symbols as comparisons. On these trials, the Co+ consisted of the symbol that was associated with both features of the sample stimulus. For example, on trials where American painter was presented as the sample, the Co+ was the symbol Pollock because that is the stimulus that is associated with both features. On these trials one of three different negative comparisons were presented: a Co− that was not related by

Table 4

Assessment of symbol–dual feature relations.

		Type of Co−		
	Co+	N-no/V-no	N-no/V-yes	N-yes/V-no
Sa	+/+	−/−	−/+	+/−
1	ap	fw gw fc gc	fp gp	aw ac
2	fp	aw gw ac gc	ap gp	fw fc
3	gp	aw fw ac fc	ap fp	gw gc
4	aw	fp gp fc gc	fw gw	ap ac
5	fw	ap gp ac gc	aw gw	fp fc
6	gw	ap fp ac fc	aw fw	gp gc
7	ac	fw gw fp gp	fc gc	ap aw
8	fc	ap gp aw gw	ac gc	fp fw
9	gc	ap fp aw fw	ac fc	gp gw

Note. Condition varied based on the nationality- and vocation-based features shared between the Co+ and Co−. The + and − signs correspond to shared nationality-based and shared vocation-based features, respectively. The Sa and Co+ listed in a horizontal section was presented with all of the Co−s in the same section. Specific details regarding the comparison pairs and the order of testing are provided in the text.

training with either of the features related to the sample (i.e. Debussy who is neither American or a painter), or with only one feature that had become related to the sample (i.e. Gershwin who is American but not a painter) or the other feature that had become related to the sample (i.e., Renoir who is not American but is a painter). These test trials were used to test for the symmetrical property of the relations between each name and the combined features, nationality and vocation. This test was analogous to asking the participant to identify the name of the individual with the pair of features used as the sample stimulus. The correct performance on these tests indicated that the pair of features in the sample had become related to a specific name presented as the comparison.

Phase 7: Reinstatement of feature–category relations. This phase repeated feature-to-category training as conducted in Phase 2. It was done to ensure that the feature-category relations were intact immediately before the administration of the classification tests.

Phase 8: Classification tests. This phase evaluated whether participants categorized the symbols into different equivalence classes based on the presence of the previously trained category names, vocation and nationality, and the features acquired by those symbols. Participants were presented with 36 different classification probes that are listed in Table 5. Each classification probe involved the presentation of eight trials. Each trial contained three symbols, one as a sample and two others as comparisons (e.g., Pollock: James, Renoir). The same three stimuli were presented as sample and comparisons in all eight trials. One comparison stimulus shared a vocation-based feature with the sample (e.g., Pollock: Renoir) and the other comparison shared a nationality-based feature with the sample stimulus (e.g., Pollock: James). Thus, both comparison stimuli were equally related to the sample in the absence of category names. Four of the eight trials were presented with one category name (e.g., Vocation) along with the sample, and the other four were presented with the other category name along with the sample (e.g., Nationality). Thus, each trial had a correct comparison: that which shared a feature with the sample that was in the category indicated by the category label presented in that trial. On these trials, the category and sample stimuli were presented as compound stimuli separated by a ''/''. The category/sample and comparison stimuli were presented in the array of an isosceles triangle with the category/sample compound at the vertex and the comparisons at the ends of the base.

The 36 different classification probes were presented in nine separate blocks, each of which contained four classification probes. Each classification probe in Table 5 is identi-

Table 5

The 36 classification probes used to evaluate the classification of symbols based on prevailing category name and the acquired vocation- and nationality-based features of the symbols.

	Probe	Cx	Sa	Co+	Co−
Block 1	1	V	1-ap	2-fp	5-fw
		N	1-ap	5-fw	2-fp
	2	V	5-fw	4-aw	2-fp
		N	5-fw	2-fp	4-aw
	3	V	2-fp	1-ap	5-fw
		N	2-fp	5-fw	1-ap
	4	V	4-aw	5-fw	1-ap
		N	4-aw	1-ap	5-fw
Block 2	5	V	1-ap	2-fp	7-ac
		N	1-ap	7-ac	2-fp
	6	V	8-fc	7-ac	2-fp
		N	8-fc	2-fp	7-ac
	7	V	2-fp	1-ap	8-fc
		N	2-fp	8-fc	1-ap
	8	V	7-ac	8-fc	1-ap
		N	7-ac	1-ap	8-fc
Block 3	9	V	1-ap	3-gp	4-aw
		N	1-ap	4-aw	3-gp
	10	V	6-gw	4-aw	3-gp
		N	6-gw	3-gp	4-aw
	11	V	3-gp	1-ap	6-gw
		N	3-gp	6-gw	1-ap
	12	V	4-aw	6-gw	1-ap
		N	4-aw	1-ap	6-gw
Block 4	13	V	1-ap	3-gp	7-ac
		N	1-ap	7-ac	3-gp
	14	V	9-gc	7-ac	3-gp
		N	9-gc	3-gp	7-ac
	15	V	3-gp	1-ap	9-gc
		N	3-gp	9-gc	1-ap
	16	V	7-ac	9-gc	1-ap
		N	7-ac	1-ap	9-gc
Block 5	17	V	2-fp	3-gp	8-fc
		N	2-fp	8-fc	3-gp
	18	N	9-gc	8-fc	3-gp
		N	9-gc	3-gp	8-fc
	19	V	3-gp	2-fp	9-gc
		N	3-gp	9-gc	2-fp
	20	V	8-fc	9-gc	2-fp
		N	8-fc	2-fp	9-gc
Block 6	21	V	4-aw	5-fw	7-ac
		N	4-aw	7-ac	5-fw
	22	V	8-fc	7-ac	5-fw
		N	8-fc	5-fw	7-ac
	23	V	5-fw	4-aw	8-fc
		N	5-fw	8-fc	4-aw
	24	V	7-ac	8-fc	4-aw
		N	7-ac	4-aw	8-fc
Block 7	25	V	4-aw	6-gw	7-ac
		N	4-aw	7-ac	6-gw
	26	V	9-gc	7-ac	6-gw
		N	9-gc	6-gw	7-ac
	27	V	6-gw	4-aw	9-gc
		N	6-gw	9-gc	4-aw
	28	V	7-ac	9-gc	4-aw
		N	7-ac	4-aw	9-gc
Block 8	29	V	6-gw	5-fw	9-gc
		N	6-gw	9-gc	5-fw
	30	V	8-fc	9-gc	5-fw
		N	8-fc	5-fw	9-gc
	31	V	5-fw	6-gw	8-fc
		N	5-fw	8-fc	6-gw
	32	V	9-gc	8-fc	6-gw
		N	9-gc	6-gw	8-fc
Block 9*	33	V	3-gp	2-fp	6-gw
		N	3-gp	6-gw	2-fp
	34	V	5-fw	6-gw	2-fp
		N	5-fw	2-fp	6-gw
	35	V	2-fp	3-gp-	5-fw
		N	2-fp	5-fw	3-gp
	36	V	6-gw	5-fw	3-gp
		N	6-gw	3-gp	5-fw

(*Continued*)

* Data not recorded due to a programming error. See text for details.

Note. Each row contains information for one of the classification probes. The first column indicates the block number that contained the classification probes. The second column contains the probe number and the third contains the category name that is presented during a probe. The fourth, fifth and sixth columns indicate the names presented in each classification probe and the features associated with each name.

fied by a number (1–36). Each probe was presented on eight trials and all trials in a probe were presented with uninformative feedback. Thus, a block contained 32 trials which were presented in a randomized sequence without replacement. A programming error, however, resulted in the presentation of only eight of the nine test blocks and thus only 32 of the 36 classification probes. The blocks were presented serially but without rest periods between blocks. The performances that could be produced by the classification tests and their interpretation will be described in the Results and Discussion section.

Phase 9: Reversal design and control by Vocation and Nationality category names. To determine the effects of the presence of the category names on the performances evoked by the classification probes on a within-subject basis, one participant was tested using an ABA reversal design. At the completion of Phase 8 (the first A in the reversal design), the classification test was repeated but with no category names on any trials (the B condition in the reversal design). Once completed, the subject was once again presented with the classification test as conducted in Phase 8 with

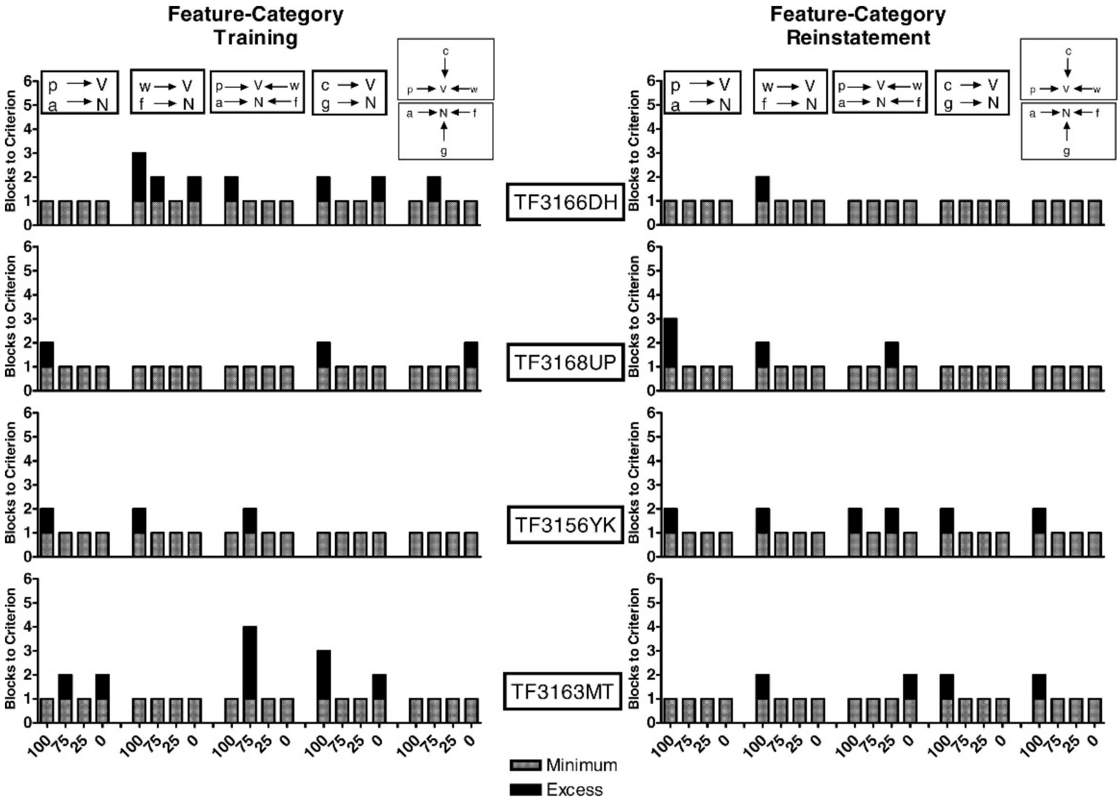

Fig. 2. Performances of all participants during feature–category training. Data are presented for each phase of training. The specific relations, trained and tested, are indicated in the boxes above each segment. Lower case letters represent the features (p = painter, w = writer, c = composer, a = American, f = French, g = German) and upper case letters represent the category names (V = vocation, N = nationality). Each arrow connects two stimuli that were the sample and comparison in a conditional discrimination with the sample at the tail of the arrow and the comparison at the head of the arrow. Feedback level during each stage of training and testing is indicated on the x-axis and number of trials to the percent-correct criterion is indicated on the y-axis. The lower segments of each bar (gray) indicate the minimum number of blocks required for training or testing while the upper segments (black) indicate the number of blocks in excess of the minimum required to reach criterion. The absence of a black bar indicates that the percent-correct criterion was met in the minimum number of blocks required.

category stimuli in all trials (the second A condition in the reversal design).

RESULTS AND DISCUSSION

Participant retention. Of the 11 participants who began the experiment, 3 did not acquire the feature–category name relations after 90 min of training in Phase 1 and were dismissed. The remaining 8 participants acquired the feature–category name relations in less than 19 min. Four of these 8 participants did not form the first-trained vocation-based equivalence classes and were also dismissed. Additional research will be needed to determine the basis of these failures. The 4 remaining participants formed the second-trained vocation-based equivalence classes and went on to complete the experiment. Their data are presented for each phase of the experiment.

Feature-category training. The left panels of Figure 2 represent results for each participant during acquisition of the feature–category name relations. The feature–category conditional discriminations were formed in few blocks, indicating rapid acquisition (see segments 1, 2, and 4). Accuracy of responding was minimally disrupted by reduction of feedback. In addition, when new conditional relations were trained, (see segments 3 and 5) there was no disruption of the previously established

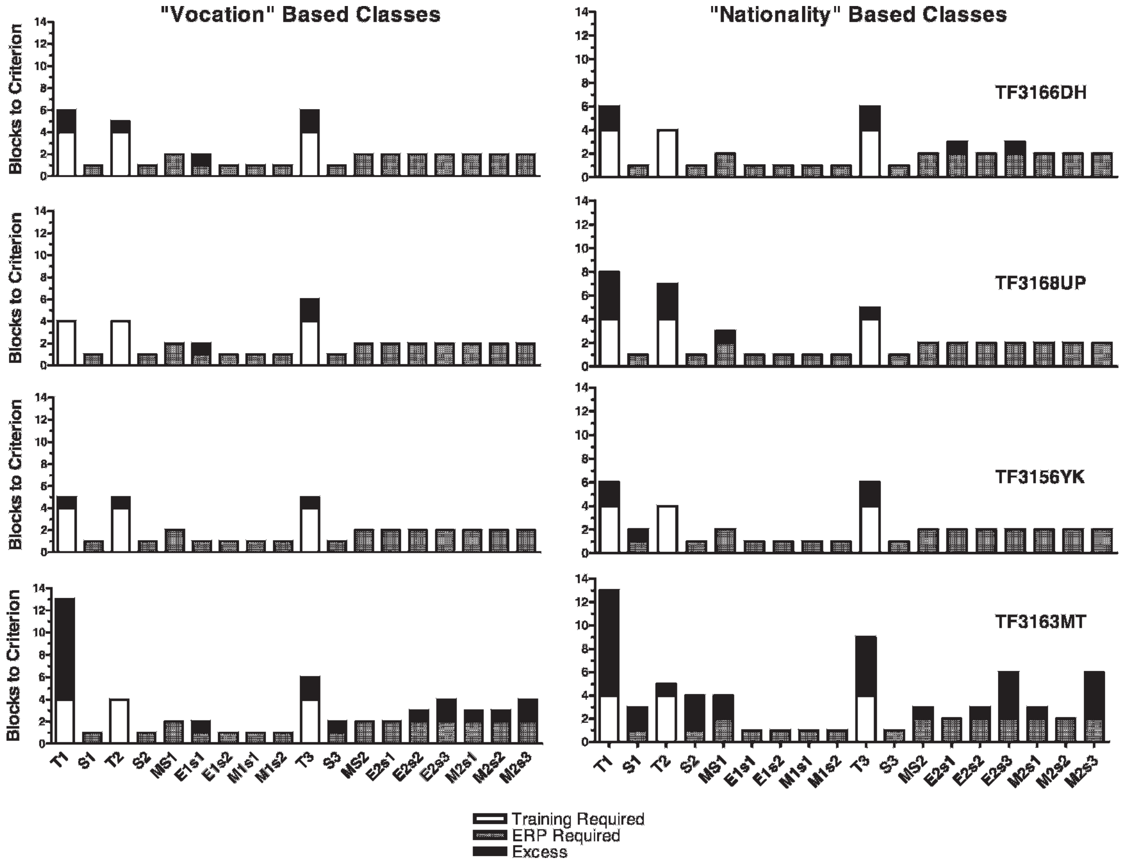

Fig. 3. Performances of all participants during the establishment of two 4-member equivalence classes. The graphs in the left panel represent performances during the establishment of the ''vocation''-based equivalence classes. The graphs in the right panel represent performances during the establishment of the ''nationality''-based equivalence classes. Training and testing blocks are indicated on the x-axis and correspond to the blocks described in Tables 2 and 3. Blocks that were presented multiple times are denoted with a lower case ''s'' followed by a number (1, 2 or 3) indicating the sequence of their presentation. The number of blocks required to meet the percent-correct criterion is indicated on the y-axis. On training blocks, the white segment of the bar indicates the minimum number of blocks required. On emergent relation probe (ERP) test blocks, the gray segment of the bar indicates the minimum number of blocks required. The black segment of the bars indicate the number of trials in excess of the minimum that were required to meet the percent-correct criterion. The absence of a black bar indicates that the percent-correct criterion was met in the minimum number of blocks required.

relations that were included in those training blocks.

Equivalence class formation. Figure 3 displays the data that depicts the establishment of the three vocation-based and the three nationality-based equivalence classes, in the left and right hand columns, respectively. All 4 participants formed the vocation- and nationality-based equivalence classes in Phases 4 and 5. The baseline symbol–feature conditional discriminations were formed rapidly, with little variability across the different baseline relations for a given participant. With the exception of 1 participant most of the derived relations emerged in the first test block, demonstrating the essentially immediate formation of the four-member equivalence classes. In general, there was little variability in class formation across participants. Finally, the second learned equivalence classes were formed as quickly as the first learned classes.

Symbol–dual features tests. The dual feature–symbol and symbol–dual feature tests evaluated the emergence of a relation between each symbol and the pair of nationality and vocation features that had been linked separately with each symbol during the formation of the equivalence classes. As seen in Figure 4,

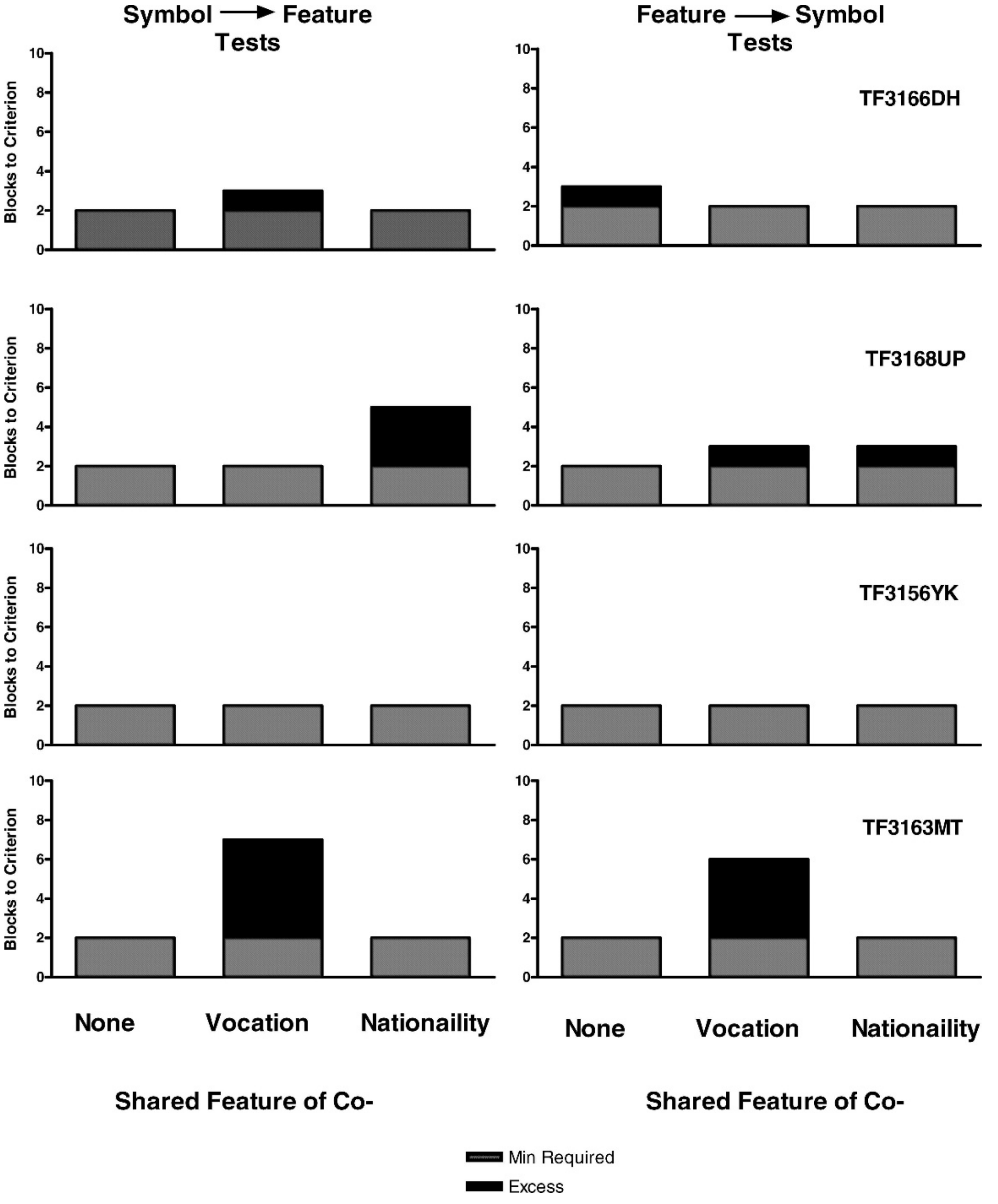

Fig. 4. Performances of all participants during feature–symbol and symbol–feature tests. The graphs in the left and right columns represent the results of the Symbol→ Feature and Feature → Symbol tests, respectively. Test type varied in terms of the negative comparison (Co−) included in a test trial, as indicated by values on the abscissa. None indicates that the Co− did not contain any features that had been trained to the sample symbol, Vocation indicates that the Co− contained the same ''vocation'' feature that had been trained to the sample symbol but contained a different ''nationality'' feature. Finally, Nationality indicates that the Co− contained the same ''nationality'' feature that had been trained to the sample symbol but contained a different ''vocation'' feature. The number of blocks required to meet the percent-correct criterion is indicated on the y-axis. The gray segment of each bar indicate the minimum number of blocks required to pass the test. The black segment of each bar indicates the number of trials in excess of the minimum that were required to pass the test.

Table 6

Frequency measures of five theoretical outcomes of a representative classification probe.

Code	Cxt	LEQ		Interpretations
		ZOJ	CAZ	
Cx-D	**N**	4	0	Direct control by context and acquired features
	V	0	4	
Cx-I	**N**	0	4	Inverse control by context and acquired features
	V	4	0	
Nat	**N**	4	0	No contextual control
	V	4	0	Control by acquired nationality features
Voc	**N**	0	4	No contextual control
	V	0	4	Control by acquired vocation features
Other	**N**	2	2	No identifiable control by context of acquired features
	V	2	2	

Note. The theoretical patterns of comparison selection illustrated in each of the five horizontal segments indicate unique sources of stimulus control for a representative classification probe. Each type of stimulus control is represented symbolically in the first column. The second column indicates the prevailing contextual cue on a probe trial while the third and fourth columns represent the comparison stimuli presented along with the sample (LEQ). The numbers presented below the comparison stimuli indicate the number of probe trials (out of four) that occasion selection of that comparison selection. Interpretations of each outcome are presented in the fifth column.

in the symbol–dual feature tests, participants typically selected the comparison that contained both features acquired by the symbol, instead of the comparisons that included only one feature that was shared with the sample, or no features that were shared with the sample. In the dual feature–symbol tests, participants typically selected the symbol that corresponded to the pair of features presented as a sample instead of symbols that included only one feature that was shared with the sample, or no features that were shared with the sample. Specifically, of the 24 types of probes, the correct comparisons were selected in the minimal number of blocks with 17 probes, in one block more than the minimum with 4 probes, and in three, three, four, and five blocks more than the minimum for the remaining three probes. Although learned separately, each symbol became associated with the combined presence of both acquired features.

Feature–category reinstatement. The panels in the right column of Figure 2 illustrate the reacquisition of the feature–category relations after the formation of nationality- and vocation-based equivalence classes and the emergence of symbol–dual feature and dual feature–symbol relations. A number of the relations required reacquisition. The degree of retraining was like that needed for the initial establishment of the feature–category relations. Thus, the passage of time and/or the establishment of the equivalence classes and the administration of the symbol–dual feature and dual feature–symbol tests probably disrupted the previously trained feature category relations. Retraining, however, insured that the feature–category relations were intact prior to the classification tests.

Contents of a classification probe. The final phases in the experiment determined whether the symbols would be classified as members of different equivalence classes based on the presence of a contextual cue that signaled attention to particular features that had been acquired by the symbols. This was accomplished with the presentation of the classification probes listed in Table 5. Each classification probe could produce one of five patterns of responding, each of which indicates control of responding by a different aspect of the stimuli used in a trial. Thus, each pattern represents a different stimulus-control topography (McIlvane & Dube, 2003). Table 6 illustrates possible patterns of responding and the forms of stimulus control implied by each pattern for a representative classification probe presented four times in the presence of the nationality-based contextual cue (N) and four times in the presence of the vocation-based contextual cue (V). In this example, symbol 1 (LEQ) is presented as the sample and symbols 2 (ZOJ) and 4 (CAZ) are presented as comparisons. The stimulus control topographies are described below.

Experimenter-defined contextual control (D-Cxt). Direct joint control by the category cue and the features acquired by the symbols would be indicated by the selection of comparison 2 on all trials in which N was the contextual cue, and comparison 4 on all trials in which V was the contextual cue. This pattern of responding would indicate that class membership of each symbol depended on the prevailing contextual cue and the features shared by the samples and comparisons in each probe trial.

Inverse contextual control (I-Cxt). Inverse joint control by the category cue and the features acquired by the symbols would be indicated by the selection of comparison 4 when N was the contextual cue, and comparison 2 when V was the contextual cue (i.e, participants selected the comparison that did not share the nationality feature with the sample in the presence of the nationality cue and the comparison that did not share the vocation feature with the sample in the presence of the vocation cue). The evocation of this pattern of responding in all probes would indicate that class membership of each symbol depended on the prevailing contextual cue and the features not shared by the samples and comparisons on each probe trial.

Feature-based selection by vocation (f-Voc). Control of behavior by the vocation-based feature shared by the sample and comparison stimuli would be indicated by the selection of the the comparison that shared the vocation feature with the sample on all trials. This pattern of responding in all probes would also indicate the absence of discriminative control by the nationality and vocation category cues.

Feature-based selection by nationality (f-Nat). Control of behavior by the nationality-based feature shared by the sample and comparison stimuli would be indicated by the selection of the comparison that shared the vocation feature with the sample on all trials. This pattern of responding in all probes would also indicate the absence of discriminative control by the nationality and vocation category cues.

Indeterminate stimulus control (Other). Indeterminate control by acquired features or contextual stimuli would be indicated by the selection of each comparison with equal frequency in the presence of the N or V contextual cues.

Criterion values for each form of stimulus control. Each form of stimulus control was demonstrated if performances were as indicated on all eight trials or if one trial yielded a performance that was not consistent with the designated pattern of responding.

Performances in classification tests. Figure 5 provides the results of the classification tests for 4 participants. Each panel is for a separate participant and provides a longitudinal characterization of the stimulus control topographies produced by each of the 32 classification probes that are identified by numbers as listed in Table 5. Each line on the ordinate corresponds to one of the five stimulus control topographies described in Table 6. The stimulus control topography produced by each classification probe is represented by a dot above that classification probe number indicated on the abscissa. The row on which the dot is placed indicates the form of stimulus control that is the determinant of responding for the corresponding classification probe. Only 32 of the 36 probes were presented due to programming error. The fact that data for the last four probes were not collected, however, does not preclude a demonstration of the classification of symbols based on contextual stimuli and the features acquired by the symbols.

As shown in Figure 5, for participant TF3166DH, 16 of the 32 classification probes produced selections of the comparisons that shared the vocation feature with the prevailing sample, while another 11 produced the selection of the comparisons that shared the nationality features with the sample stimuli. Although these performances indicated control by the features acquired by the stimuli in the probes, they also indicated the absence of control by the category labels.

Participant TF3168UP exhibited an unusual pattern of joint control by the category names and the features acquired by the symbols. For this participant, the pattern of responding consistent with experimenter-defined joint control was evoked by 15 of 32 probes, and inverse joint control was evoked by another 15 of 32 probes. These two patterns occurred in a ''dual alternation'' throughout the classification test where responding on two adjacent probes was consistent with joint control by the category names and acquired features followed by two adjacent probes that produced selections consistent with inverse joint control. Despite considerable effort, we have not been able to identify any variable that could account for this puzzling dual alternation. These results are a testimony to the richness and variability of problem solving strategies and subject-generated rules that can interact with contingency-induced forms of hierarchically based conditional control.

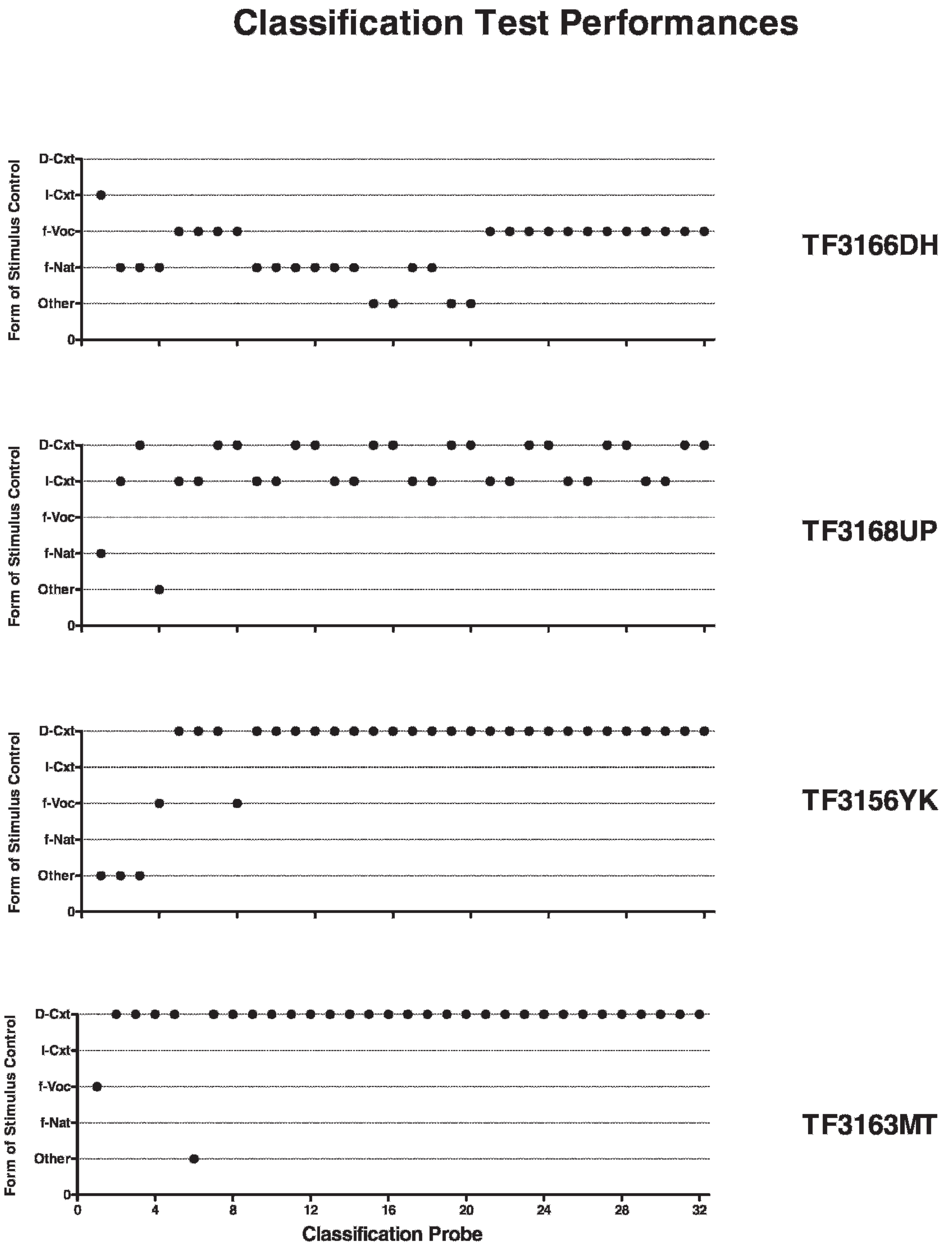

Fig. 5. Performances of 4 participants during classification tests. Each panel contains data for a separate participant. Each of the 32 classification probes are indicated numerically on the abscissa with the stimulus control topographies produced by each on the ordinate, with definitions of each drawn from Table 6.

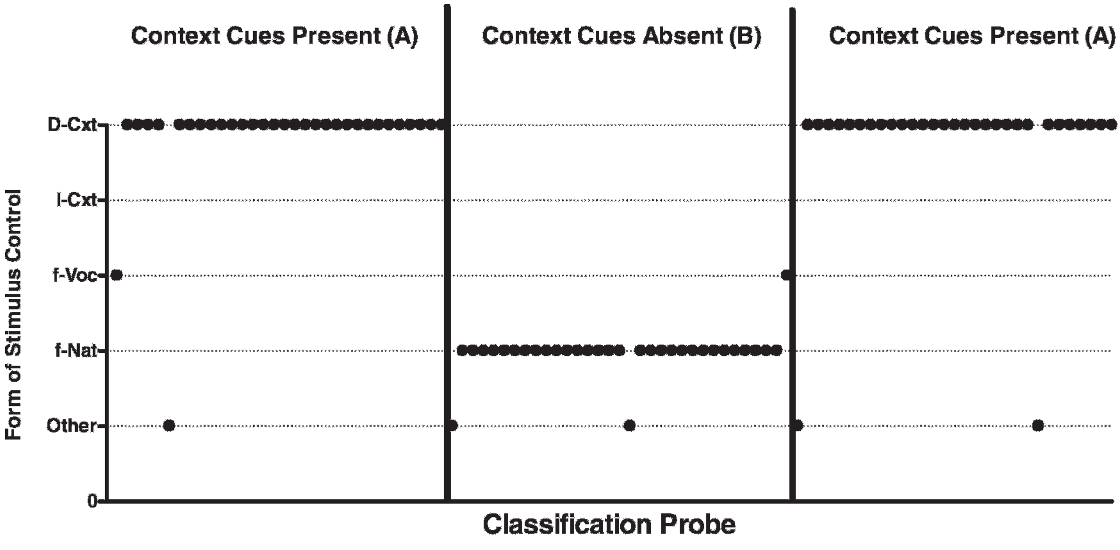

Fig. 6. Performances produced by classification probes with and without category labels for subject TF3163MT, in a format similar to that used in Figure 5. The left and right segments indicate performances during the first and third set of classification probes in which symbols were presented with category names. The middle segment indicates performances during classification tests presented without category names. In each segment, successive data points represent classification probes 1–32.

For TF3156YK, the performances during the first three classification probes indicated no identifiable control by context or acquired features. The fourth probe yielded a shift in performance that documented the emergence of joint control by the category names in combination with the acquired features of the symbols that was maintained for the remaining 29 probes. Because this pattern of responding was consistent on 231 consecutive trials of the 256 trials in the classification test, it could have occurred by chance with $p = 2.66e^{-43}$ (i.e., 231 $\times$ 0.05). For Participant TF3163MT, all but two of the classification probes produced responding that indicated joint control by the category name and acquired features of the symbols. Produced on 248 of the 256 trials in the classification test, these performances could have occurred by chance with $p = 3.54e^{-63}$ (i.e., 248 $\times$ 0.05).

Within-participant demonstration of contextual control. The data in Figure 5 demonstrated contextual control of symbol assignment to different equivalence classes across participants. Figure 6 presents additional data obtained with Participant TF3163MT which documented the effect of contextual control on a within-participant basis. For this participant, the 32-probe classification test was presented three times, all without informative feedback. In the first and third iteration, the category labels were included in each trial, but in the middle iteration, the trials were presented without the category labels. The three tests, then, constituted a presence-absence-presence or A-B-A evaluation of the effect of category cues on the classification of symbols into different equivalence classes.

In the tests conducted with contextual labels, the assignment of class membership to a given symbol varied according to the prevailing category name. In the test conducted with no contextual cues, assignment of class membership was based almost exclusively on the nationality-based features acquired by the stimuli in the probes. The immediate shift in performances produced by the presence and absence of the contextual cues, then, provided a within-participant demonstration of the effects of contextual cuing on shifts in class membership of symbols which was also based on the features acquired by the symbols.

GENERAL DISCUSSION

Contextual function of category labels. A contextual stimulus controls a set of discriminative performances in the presence of novel discrimination problems (Cumming & Berryman, 1961; Griffee & Dougher, 2002; Lynch & Green, 1991; Mackay, 1991; Meehan & Fields, 1995; Perkins, Dougher, & Greenway, 2007). In the present experiment, each classification probe was a novel conditional discrimination problem. When presented with the category stimuli, different performances were evoked by the combination of category and feature stimuli. Thus, the category names were functioning as contextual cues that determined the assignment of symbols to different equivalence classes.

Symbol classification conducted with contextual cues. Each classification trial contained a sample and two comparison stimuli, each of which had acquired one feature from each of two categories. The sample shared one feature with one comparison and the other with the second comparison. Based on shared features, each comparison was equally related to the sample. Thus, it was impossible to select a correct comparison. When a category name was included in a trial, however, it signaled attention to a specific feature in that category which had been acquired by the stimuli during training. Thus, the correct comparison was the one that shared a feature from that category with the sample stimulus. Thus, the performances produced by the classification probes documented three nationality-based equivalence classes in the presence of the nationality-based category cue (123a, 456f, and 789g) and three vocation-based equivalence classes in the presence of the vocation based category cue (147c, 258p, and 369w). Accordingly, each symbol functioned as a member of two different equivalence classes: Symbol 1 in classes 123 and 147, symbol 2 in classes 123 and 258, symbol 3 in classes 123 and 369, symbol 4 in classes 456 and 147, symbol 5 in classes 456 and 258, symbol 6 in classes 456 and 369, symbol 8 in classes 789 and 258, and symbol 9 in classes 789 and 369. The results observed for Participants TF3163MT and TF3156YK demonstrated the classification of symbols into different equivalence classes based on category label and the features in each category that had been acquired by the symbols.

Failed symbol classification and inattention to context. One participant in the present experiment did not show any contextual control of symbol classification. For this participant, a large number of consecutively presented probes produced responding that was correlated with the nationality-based features after which responding switched abruptly to responding that was correlated with the vocation-based features. This absence of contextual control could not be attributed to a deterioration of the relations between each category cue and its related feature stimuli because the symbol–dual feature relations were intact immediately prior to the administration of the classification tests. Thus, while attending to features acquired by the symbols in both categories, this participant was not attending to category membership of the features. This problem ought to be remediated or prevented by the use of procedures that would enhance control by the category labels that should have been functioning as contextual stimuli in the classification tests. For example, although the category names served as comparisons during feature-category training they served as samples during the classification tests. Perhaps, control by the category names during the classification tests could be enhanced by presenting symmetry tests immediately after the establishment of feature–category relations. These tests, which would involve the presentation of category names as sample stimuli, might serve to enhance control by the category labels in the final context test. To summarize, although the parameters of the present experiment were sufficient to induce symbol classification based on contextual cues and features acquired by symbols, additional research is needed to identify variables that will increase the reliability of this phenomenon across participants.

Separability of nationality- and vocation-based equivalence classes in the absence of contextual cues. After forming three vocation-based equivalence classes with the nine symbols, three nationality-based equivalence classes were established with the same nine symbols but different mixes of symbols became members of the latter classes. Once the latter classes were formed, each symbol shared a vocation-based feature with two symbols and a nationality-based feature with two other symbols. Even so, the nationality-based classes emerged and remained separate from the vocation based classes in the absence of the contextual cues. This occurred because of the particular symbols used as sample, positive, and negative comparisons and the features that had been acquired by each, as illustrated in Table 5.

For example, in the 1-2-5 probe, symbol 1 had become related to features (a) and (p), positive comparison 2 had become related to features (f) and (p), and negative comparison 5 had become related to features (f) and (w). Because the Co+ and Co− contained the same nationality-based feature (f), the vocation-based feature could not be used to identify the Co+. Rather, the feature common to the two comparisons had to become discriminative for attending the vocation-based features acquired by the symbols. In contrast, the same vocation-based feature (p) had become related to the sample and the positive comparison. Thus, attending to the feature shared by the sample and one of the comparisons led to the selection of the comparison that was from the same vocation-based class as the sample symbol. The same operations governed performances evoked by the other nationality-based probes which documented the emergence of the nationality-based equivalence classes.

Attention to "absent" features, class separability and symbol classification. In prior experiments, the features of the stimuli that were classified were present at the time of classification. In the present experiment, symbol-classification was based on features that had been acquired by each symbol through prior training but were absent at the time of testing. Thus, the results of the present experiment extend the demonstrations of the contextual control of classification to situations in which some of the controlling stimuli were nominally absent at the time of classification. This condition prevailed during the emergence of the nationality-based equivalence classes and during the classification tests.

The classification of symbols shown in the present experiment can only be accomplished by attending to the features acquired by the symbols. The features, however, were not present at the time of symbol classification. Thus, it would appear to be a logical necessity that the subjects had to be attending to some correlate or representation of the features during each classification test trial (Cumming & Berryman, 1961; Hayes, 1992). Demonstration of this attention might be accomplished with the use of brain scanning techniques such as event-related potentials or functional magnetic imaging (Schlund, Cataldo & Hoehn-Saric, 2008). It might also be accomplished by tracking verbalizations or other precurrent behavior (Arntzen, 2006) emitted prior to comparison selection during the classification tests. Regardless of the outcomes of that sort of research, a behavioral account of the contextually controlled classification of symbols based on the features acquired by the symbols must also rely on the specification of the training and testing procedures used to induce those performances.

Hierarchical classification of verbal information in real world settings. In the present experiment, contextual cues governed the assignment of all "meaningless" stimuli into different equivalence classes based on the features acquired by each stimulus, even though those features were not present at the time of classification. As illustrated by the examples presented in the Introduction, these emergent performances are characteristic of the classification of meaningful verbal information into different categories based on context and the features that have become associated with verbal stimuli. Perhaps, then, learning to classify meaningful verbal information in natural settings reflects exposure to procedures like those described in the present experiment.

In the present experiment, not all participants learned to classify symbols based on context and acquired features. Additional research will be needed to identify procedural variations that enhance the emergence of these classification-indicative repertoires. The procedures used in the present experiment constituted only one means of inducing a classification repertoire. Additional research will be needed to identify alternative procedures that can also induce the same repertoire.

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