

## **BLOCKING THE FORMATION OF 5-MEMBER EQUIVALENCE CLASSES USING COMPLEX SAMPLES**

**BLOQUEO DE LA FORMACIÓN DE CLASES EQUIVALENTES  
DE CINCO MIEMBROS USANDO MUESTRAS COMPLEJAS**

**RUTH ANNE REHFELDT, MICHAEL CLAYTON, AND LINDA J. HAYES<sup>1</sup>**  
UNIVERSITY OF NEVADA

### **ABSTRACT**

The purpose of this experiment was to assess an example of conditions under which elements of sample stimulus compounds do not become functionally substitutable for one another, despite their contiguous arrangement. Specifically, it was questioned whether a prior history of matching-to-sample training with one element of three sample stimulus compounds would block additional, redundant elements from entering into equivalence relations when they were subsequently presented as members of sample stimulus compounds with the first elements. One of six subjects demonstrated the formation of three four-member equivalence classes, from which the additional, redundant elements of each sample stimulus compound were excluded. This subject was also the only subject for whom a blocking effect was observed. A second subject demonstrated the formation of three five-member equivalence classes, including the additional, redundant elements of each sample stimulus compound. This subject likewise did not demonstrate a blocking effect. The four other subjects did not demonstrate class formation, nor was a blocking effect observed for these subjects. Relations between the elements of each sample stimulus compound themselves were shown to be congruent with observations of class formation and blocking.

Key words: Blocking, stimulus classes, compound stimuli, mouse-clicking response, adults

### **RESUMEN**

El propósito de este estudio fue evaluar un ejemplo de las condiciones bajo las

---

<sup>1</sup> Address editorial correspondence to: Ruth Anne Rehfeldt, M.A. Department of Psychology/Mailstop 296 University of Nevada, Reno, NV 89557-0062, FAX: (702) 784-1126 e-mail: rehfeldt@pogonip.scs.unr.edu

cuales los elementos de un estímulo muestra compuesto no se vuelven funcionalmente sustituíbles uno por el otro, a pesar de su ordenación contigua. Específicamente, se preguntó si una historia de entrenamiento en igualación a la muestra con un elemento de 3 estímulos de muestra compuestos, bloquearían elementos adicionales redundantes impidiendo las relaciones de equivalencia con los primeros elementos cuando fueron presentados posteriormente como miembros de estímulos muestra compuestos. Uno de seis sujetos mostró la formación de tres clases de equivalencia de 4 miembros, de los cuales se excluyeron los elementos adicionales redundantes de cada estímulo muestra compuesto. Este sujeto fue el único en el que se observó un efecto de bloqueo. Un segundo sujeto demostró la formación de 3 clases de equivalencia de 5 miembros, incluyendo el elemento adicional redundante de cada estímulo muestra complejo. Este sujeto no demostró tampoco el efecto de bloqueo. Los otros 4 sujetos no demostraron formación de clases, ni tampoco el efecto de bloqueo. Se mostró que las relaciones entre los elementos de cada estímulo muestra compuesto, fueron congruentes con observaciones de función de clases y bloqueo.

Palabras clave: bloqueo, clases de estímulo, estímulos compuestos, respuesta de apretar el ratón, adultos

---

Behavior under control of individual unitary stimuli has been the subject of much laboratory investigation. Environments outside of the laboratory are more complex, however. Behavior is seldom controlled by single stimuli; rather, combinations of stimuli may become functionally related to behavior. For example, a child may acquire a reading repertoire following the simultaneous presentation of a picture of an object and the corresponding printed word for that object on a flashcard (e.g., Sidman, 1971). The two stimuli then may be established as discriminative for the child's spoken word response. When combinations of controlling stimuli are examined in the laboratory, they are referred to as stimulus compounds, while the stimuli constituting a given compound are described as elements of that compound. With the nearly limitless possibility of sources of stimulus control in the natural environment, it is apparent that any number of stimulus combinations may come to exert compound stimulus control. Operant and respondent control by compound stimuli have, for this reason, been an important area of investigation. A common finding is that, under certain conditions, not all elements of a stimulus compound gain equal control over behavior; some elements may come to exert a stronger influence than other elements.

The study of compound conditioning is particularly relevant to investigations of equivalence classes, due to the frequency with which verbal stimuli appear in conjunction with one another in linguistic situations. Verbal stimuli often appear in combinations with other verbal stimuli, in the form of written and spoken sentences, and their semantic meaning may vary as a

function of the presence or absence of other stimuli (see Dougher & Markham, 1994). Several recent investigations of stimulus equivalence have employed complex samples, or sample stimuli consisting of two-element stimulus compounds. In such procedures, subjects receive matching-to-sample training with compound samples and unitary comparisons, the noteworthy finding being that, when the elements of each complex sample are later separated during the test for equivalence, both elements will be shown to have entered separately into equivalence relations with the other stimuli (Markham & Dougher, 1996; Stromer & Stromer, 1990a, 1990b). Emergent relations between the elements of the compounds themselves have also been observed (Markham & Dougher, 1996). These procedures clearly increase the number of emergent relations which may result from equivalence class training. In addition, because of the appeal of stimulus equivalence as a model for semantic language processes, findings from investigations of stimulus compounds and equivalence have engendered speculations regarding the conditions sufficient for stimuli to become symbolically related. It has been suggested by some that contiguity between stimuli may, in fact, be sufficient for the development of stimulus classes (e.g., Hayes, 1992; Stromer, McIlvane, & Serna, 1993).

As previously noted, however, under some conditions the contiguous arrangement of the elements of stimulus compounds may not be sufficient for both elements to acquire functional control over behavior. Instead, a discrepancy in the degree of control exerted by the elements may be observed. The body of results that has been described as the blocking effect (Kamin, 1969) is an example of such a discrepancy. When a conditioning history is established with one stimulus, that history is likely to interfere with or block the conditioning of a second, redundant stimulus when the two stimuli are subsequently presented together as elements of a stimulus compound. The blocking effect has been observed in a variety of classical and operant conditioning procedures (e.g., Singh & Solman, 1990; Stickney & Donahoe, 1983; Williams, 1975; Williams & Heyneman, 1983), and represents an example of a situation in which, despite seemingly optimal conditions, conditioning fails to occur.

Applied research has made clear the natural-environment significance of blocking. Singh and Solman (1990), for example, reported that prior conditioning histories with pictures of objects blocked the acquisition of discriminative control by written words in mentally retarded children. The blocking effect was argued to merit attention in the teaching of reading and other language-related skills. Because stimulus equivalence seems to closely parallel linguistic repertoires, it may be worthwhile to examine the blocking effect within the context of stimulus equivalence. For example, if subjects first learn to symbolically relate a unitary sample stimulus to comparison stimuli, will

that history block a second stimulus from entering into equivalence relations with comparison stimuli when it is presented as a redundant element of a sample stimulus compound along with the first element? If so, the blocking effect may be considered an example of conditions that are insufficient for some stimuli to become class-members, despite their involvement in equivalence class training.

The purpose of the present experiment was to extend the blocking effect into the domain of stimulus equivalence. Subjects initially received matching-to-sample training with one element of three complex samples only, and then were trained with both elements of each of the three samples. During a test phase, the elements were separated, and subjects were tested for emergent relations between each element of the three complex samples and the other stimuli. If the prior history with one stimulus element of each compound did in fact block the other stimulus element from entering into relations with other stimuli, accuracy was predicted to be high for relations involving the first element, and low for relations involving the second, redundant element. Subjects were tested for relations between the elements of each compound as well, in which one element was presented as the sample stimulus and the other element was presented as a comparison. If blocking had occurred, accuracy on these relations was predicted to be low, but if blocking had not occurred, accuracy on the relations was predicted to be high.

## METHOD

### *Subjects*

Six adults (three males and three females) enrolled in undergraduate psychology courses participated as subjects and received course credit for their participation. Subjects were recruited through in-class announcements. To ensure that subjects did not inform one another of the details of the experiment, subjects were recruited from a variety of courses and were asked to not share the details of the experiment with other students. Before the experiment, all subjects signed a statement of informed consent and were told that they could withdraw from the experiment at any time, although none chose to do so. Upon completion of the study, all subjects were thoroughly debriefed.

### *Apparatus and Stimulus Materials*

Data collection and stimulus presentation were computer controlled. The experiment, programmed in Microsoft Visual Basic version 4.0, was performed using an IBM-compatible personal computer, equipped with a color monitor and two-button mouse. The computer was positioned centrally on a

60.96 cm x 60.96 cm table. Experimental sessions were conducted in a 3.66 m x 3.66 m room containing a table and chair. Figure 1 displays the fifteen arbitrarily configured stimuli that were displayed on training and test trials. Stimuli were 5-6 cm in diameter, and were arbitrarily divided into three stimulus classes.

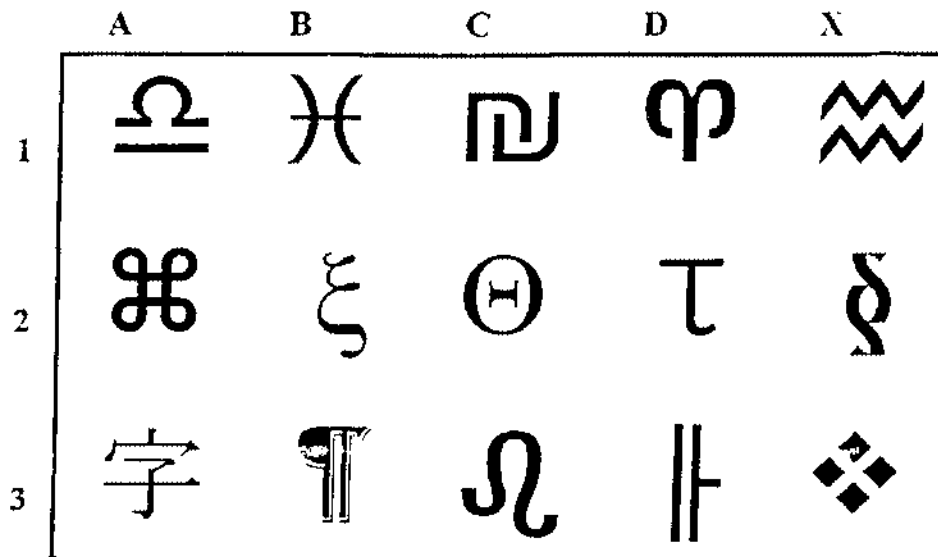


Figure 1. The fifteen stimuli used in the experiment.

#### *Procedure*

As shown in Figure 2, fifteen conditional discriminations involving either unitary samples and unitary comparisons, or compound samples and unitary comparisons were trained, and 39 novel conditional discriminations involving unitary samples and unitary comparisons were tested. Sample stimuli were presented in the top center of the screen, followed 1 s later by the display of three comparison stimuli, evenly spaced across the bottom of the screen. Compound samples consisted of stimulus pairs presented 3 mm apart on the computer screen. The left and right position of each sample stimulus element varied randomly across trials, as did the location of each comparison stimulus. The subject selected a comparison stimulus by clicking the computer mouse upon it. Following correct matches during training, sample stimuli and matching comparisons became outlined in black for 1.5 s, after which the statement "Excellent! One point!" was displayed and one point was added to the subject's

current point-total. Following incorrect matches during training, the statement, "Wrong! Minus one point!" was displayed and one point was subtracted from the subject's current point-total. All trials were separated by a 1-s intertrial interval. Point totals were displayed in the lower left-hand corner of the computer screen throughout training, but not during testing, as no feedback was given during testing. Data were collected over the course of one session with each subject. Sessions lasted approximately 1 hr for all subjects.

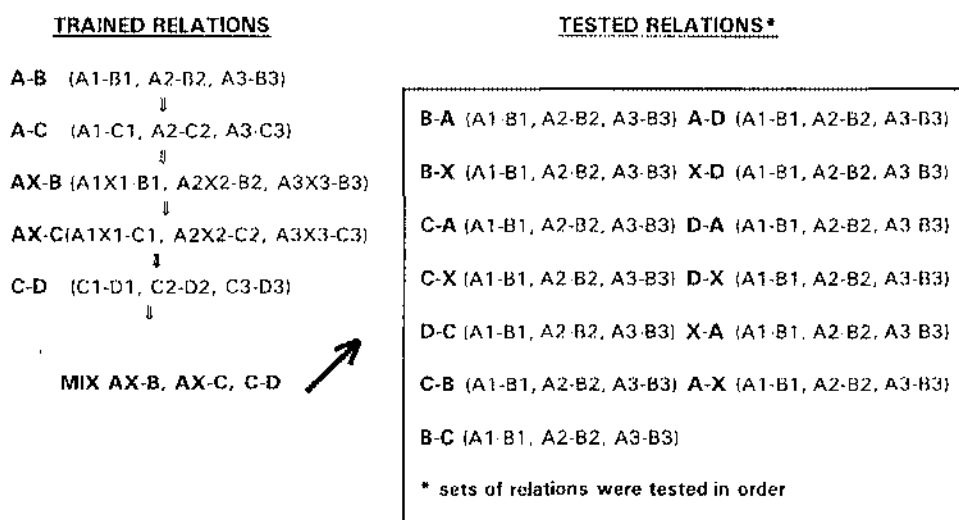


Figure 2. Schematic representation of the trained and tested relations.

Subjects were given the following instructions before the experiment:

"There are several sections to this experiment. Your job is to earn as many points as you can. It is important that you do your best throughout the experiment. First, a figure will appear in the center of the screen. Next, 3 figures will appear below the first figure. It is your job to choose one of the three figures. To choose one of the 3 figures, click the mouse once on the figure that is your choice. You will earn a point if you respond correctly, but will lose a point if you respond incorrectly. Please remember to do your best."

Two sets of three relations consisting of unitary samples and unitary comparisons were trained. First the A-B relations (A1-B1, A2-B2, A3-B3) were trained, followed by the A-C relations (A1-C1, A2-C2, A3-C3). Next, two sets of three relations consisting of compound samples and unitary comparisons were trained, including the AX-B relations (A1X1-B1, A2X2-B2, A3X3-B3),

followed by the AX-C relations (A1X1-C1, A2X2-C2, A3X3-C3). The C-D relations (C1-D1, C2-D2, C3-D3), consisting of unitary samples and unitary comparisons, were trained next. During all training sets, subjects were required to respond correctly on 14/15 trials, or 93% correct per 15-trial block in order to advance to the next set. Throughout each training set, the order of the sample stimulus presentations was determined randomly, but each sample stimulus could be presented no more than five times per 15-trial block. After criterion was attained on the C-D relations, the AX-B, AX-C, and C-D relations were trained together. Subjects were required to respond correctly on 25/27 trials, or 93% correct per 27-trial block of the mixed AX-B, AX-C, and C-D trials. Each set of comparisons (B1, B2, B3; C1, C2, C3; D1, D2, D3) could be presented no more than three times per 27-trial block.

Testing consisted of 78 trials, in which unitary samples and unitary comparisons were presented. Five sets of three symmetrical relations (B1-A1, B2-A2, B3-A3; B1-X1, B2-X2, B3-X3; C1-A1, C2-A2, C3-A3; C1-X1, C2-X2, C3-X3; D1-C1, D2-C2, D3-C3), two sets of three equivalence relations (B1-C1, B2-C2, B3-C3; C1-B1, C2-B2, C3-B3), two sets of three transitive relations (A1-D1, A2-D2, A3-D3; X1-D1, X2-D2, X3-D3), two sets of three combined symmetry and transitive relations (D1-A1, D2-A2, D3-A3; D1-X1, D2-X2, D3-X3), and two sets of three relations between the sample stimulus elements themselves, or within-compound relations (X1-A1, X2-A2, X3-A3; A1-X1, A2-X2, A3-X3) were tested in a random order, but a demonstration of each relation was tested no more than twice.

## RESULTS

All subjects demonstrated criterion performance on A-B, A-C, AX-B, AX-C, C-D, and mixed AX-B, AX-C, and C-D training sets. Shown in Table 1 is the number of trial blocks required for each subject to attain criterion during each training set.

### *Equivalence Class Formation*

Shown in Table 2 is the proportion of trials which were responded to accurately by each subject, for each relation tested. If a subject responded accurately on at least 83%, or five out of six test trials each for the B-A, C-A, D-C, C-B, B-C, and D-A relations, the establishment of three four-member equivalence classes (A1B1C1D1, A2B2C2D2, and A3B3C3D3) was concluded. The table shows that Subjects 1 and 2 did meet this criterion, thus demonstrating the formation of three four-member equivalence classes. Subject 1 also performed with 100% accuracy on test trials for the X-A and A-X

ting the formation of three five-member classes, including the Subjects 3, 4, 5, and 6 did not perform with at least 83% ailing to form four-member classes.

ial blocks to criterion for each training set per subject.

Training Set						
Subject	A-B	A-C	AX-B	AX-C	C-D	MIX
1	2	3	1	1	2	1
2	1	2	1	1	1	1
3	8	2	1	1	2	1
4	1	3	2	1	1	1
5	3	3	1	1	2	1
6	3	2	2	2	1	1

oportion of trials correct for each tested relation per subject

Relation											
X	C-A	C-X	D-C	C-B	B-C	A-D	X-D	D-A	D-X	X-A	A-X
0	1.00	1.00	1.00	1.00	0.83	1.00	1.00	1.00	1.00	1.00	1.00
7	1.00	0.50	1.00	1.00	1.00	0.83	0.83	1.00	0.50	0.67	0.67
0	1.00	0.50	1.00	0.50	0.33	0.83	0.33	0.83	0.33	0.17	0.33
7	0.33	0.83	1.00	0.00	0.50	0.50	0.33	0.50	0.50	0.50	1.00
3	0.83	0.67	1.00	0.67	1.00	0.67	0.50	1.00	0.50	0.83	0.67
7	0.67	0.33	0.83	0.50	0.33	0.50	0.17	0.50	0.17	0.00	0.33

was evaluated by visually comparing the proportion of accurate t trials for symmetry, transitivity, and combined symmetry and ns in which elements A1, A2, or A3 were presented as sample imuli, to the proportion of correct responses on test trials for

symmetry, transitivity which elements X1, X2. If the proportion of a test trials assessing the "B," "C," and "L" relations between the elements were held equivalence classes.

Figure 3 disp for symmetry, transi shown separately for trials in which the examination of Figure from entering into equ trials for the D-A an higher accuracy on te substantially lower a presented. Substanti trials in which the "A" elements were pre demonstrated equiva inferred from their p demonstrate the effe

#### *Within-Compound Re*

Figure 4 pri establishment of relat within-compound reli subject. Subjects w within-compound rela trials for the A-X and also demonstrated th the emergence of with the blocking effect as to demonstrate the er 3, 4, 5, and 6.



symmetry, transitivity, and combined symmetry and transitivity relations in which elements X1, X2, or X3 were presented as sample or comparison stimuli. If the proportion of accurate responses appeared to be substantially higher on test trials assessing the emergence of relations between the "A" elements and the "B," "C," and "D" stimuli than on test trials assessing the emergence of relations between the "X" elements and the "B," "C," and "D" stimuli, the "A" elements were held to have blocked the entry of the "X" elements into equivalence classes.

Figure 3 displays the proportion of test trials responded to accurately for symmetry, transitivity, and combined symmetry and transitivity relations, shown separately for trials in which the "A" elements were presented and for trials in which the "X" elements were presented, for each subject. An examination of Figure 2 and Table 2 reveals that the "X" elements were blocked from entering into equivalence classes for Subject 2. With the exception of test trials for the D-A and D-X relations, Subject 2 responded with substantially higher accuracy on test trials in which the "A" elements were presented, and substantially lower accuracy on test trials in which the "X" elements were presented. Substantial differences in accuracy also can be seen between test trials in which the "A" elements were presented and test trials in which the "X" elements were presented for Subjects 3 and 6, but neither subject demonstrated equivalence class formation, so a blocking effect cannot be inferred from their performance. Likewise, Subjects 1, 4, and 5 did not demonstrate the effect.

#### *Within-Compound Relations*

Figure 4 presents the proportion of test trials assessing the establishment of relations between the elements of each complex sample, or within-compound relations, which were responded to accurately by each subject. Subjects were assumed to have demonstrated the emergence of within-compound relations if they performed with at least 83% accuracy on test trials for the A-X and X-A relations. The figure shows that only Subject 1, who also demonstrated the formation of three five-member classes, demonstrated the emergence of within-compound relations. Subject 2, who also demonstrated the blocking effect as well as the formation of three four-member classes, failed to demonstrate the emergence of within-compound relations, as did Subjects 3, 4, 5, and 6.

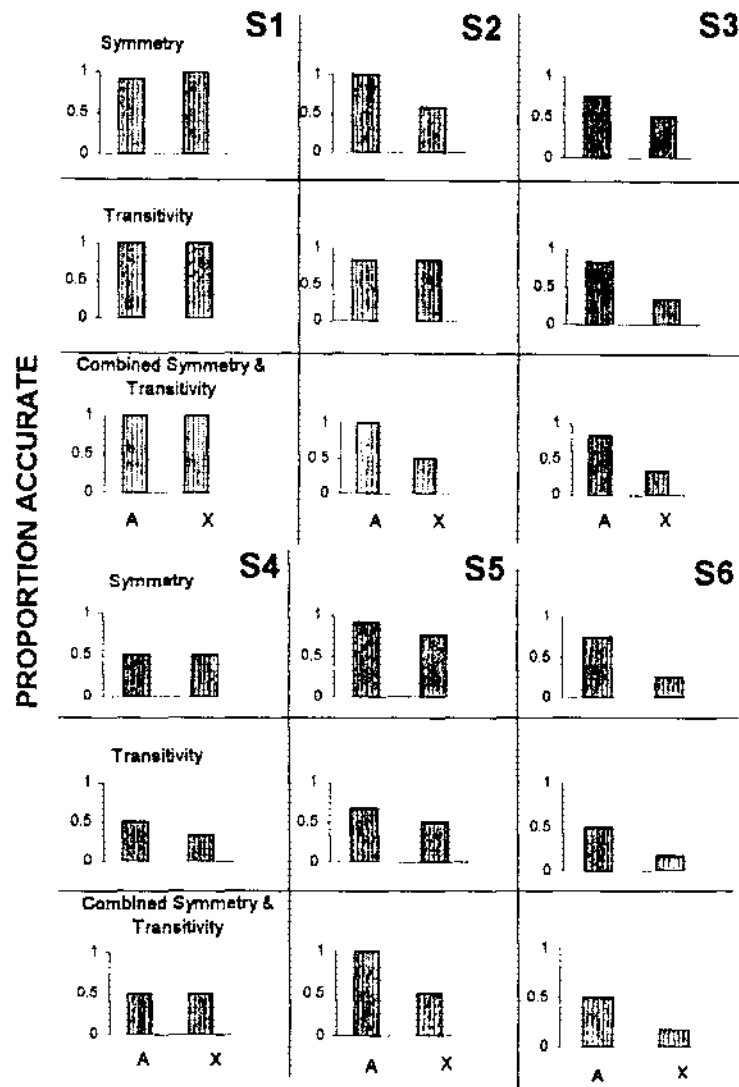


Figure 3. Proportion of test trials which were responded to accurately for relations involving the "A" elements and for relations involving the "X" elements, per subject.

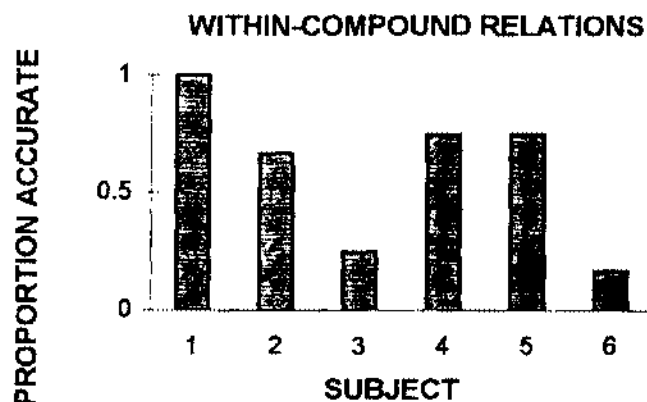


Figure 4. Proportion of test trials for within-compound relations between the "A" and "X" elements which were responded to accurately per subject.

## DISCUSSION

The results from this experiment indicate that a prior history of matching-to-sample training with unitary sample stimuli blocked the entry of additional, redundant sample stimulus elements into equivalence classes, for one of six subjects only. The same subject also demonstrated the formation of three four-member equivalence classes (A1B1C1D1, A2B2C2D2, and A3B3C3D3), yet failed to demonstrate the emergence of relations between the elements of each sample stimulus compound. Only one other subject demonstrated the formation of equivalence classes; in this case, three five member classes (A1X1B1C1D1, A2X2B2C2D2, and A3X3B3C3D3) were established, and the emergence of relations between the elements of each sample stimulus compound were also observed. The four subjects who failed to demonstrate the formation of equivalence classes also failed to demonstrate the emergence of within-compound relations.

Three four-member equivalence classes (A1B1C1D1, A2B2C2D2, and A3B3C3D3) were held to be established if a subject responded accurately on at least 83%, or five out of six test trials, for the B-A, C-A, D-C, C-B, B-C, and D-A relations. Several modifications of the employed procedure might have yielded greater success with respect to class formation: First, a requirement to observe both elements of each compound stimulus during training might have facilitated the acquisition of control by both elements of each compound. Second, test probes for the emergent relations introduced throughout training

may actually have shown the emergence of the four-member classes more effectively, as similarly might have a longer test phase. Third, subjects might have shown less difficulty in establishing the classes if the procedure was to ultimately result in three, as opposed to four, member classes. Fourth, it is possible that the AX training sets disrupted the A-B and A-C relations that had been trained previously, and a test for the formation of three three member classes (A1B1C1, A2B2C2, A3B3C3) prior to the AX training sets might have produced positive results.

A strong blocking effect was observed for one subject only, but two subjects did demonstrate a discrepancy between accuracy for the emergent relations involving the "A" stimuli and accuracy for the emergent relations involving the "X" stimuli, although this discrepancy was not large. Normally, the differences in stimulus control are quite pronounced in respondent blocking experiments. In such experiments, however, no response is required, it is either elicited with some magnitude or it is not elicited at all. During the test for equivalence, which served as the blocking test in the reported experiment, a response was always required in order to advance to the next trial. On each test trial, subjects were required to choose between three comparison stimuli, by chance alone they could have achieved at least 33% accuracy on tests for any of the relations. This may explain why accuracy on test trials for the relations involving the "X" stimuli was often 33% or higher, resulting in only a small discrepancy in the observed control by the "A" and "X" elements.

The mixed training set also may have contributed to the inconsistencies in the strength of blocking within and across subjects. First, the AX-B and AX-C relations were trained during this set, although they had been trained by themselves previously. It is thus possible that subjects completed more trials in which the "AX" compounds, versus the "A" elements alone, were presented, potentially creating more opportunities for both elements of each compound to acquire control over behavior. However, as can be seen in Table 1, all six subjects required only one training block to attain criterion during the mixed training set, such that the additional AX-B and AX-C trials were kept to a minimum. Table 1 also shows that all subjects required either the same or a greater number of trial blocks to attain criterion during the A-B and A-C training sets as they did during the AX-B and AX-C training sets, so the same argument could be applied to the greater number of trials involving the "A" elements only that subjects may have completed.

Future research might successfully demonstrate the blocking effect if the procedure employed more closely mirrors that of traditional respondent blocking experiments. First, such experiments often employ a control subjects who do not receive a prior training history with one element (e.g., Kamin, 1969). If both elements are then shown to exert functional control over the

responding of control subjects but a discrepancy is observed for the subjects who received a prior training history with one element, a blocking effect can be inferred. Second, as previously noted, a test conducted prior to compound stimulus training to assess the acquisition of control by the unitary elements is often employed in blocking experiments, allowing for clear demonstrations of the effect. These two clarifications might be addressed in subsequent research.

Subjects' performances on test trials for relations between the "A" and "X" elements are particularly interesting in light of the potential role of the contiguity between stimuli in the establishment of emergent relations. The present results suggest that for the one subject for whom blocking was observed, the contiguity of the sample stimulus elements was *not* sufficient to establish strong relations between those elements. On the other hand, for the subject who demonstrated the formation of three five-member classes, the contiguity of the sample stimulus elements was sufficient to establish strong relations between those elements. Contiguity was not a sufficient for the subjects who failed to demonstrate equivalence classes. Thus, accuracy on test trials for the establishment of the within-compound relations appears to be congruent with observations of class formation, as well as the blocking effect. Continued efforts to examine the role of contiguous stimulus arrangements in equivalence class formation would be worthwhile.

This experiment represents the start of an analysis of the conditions under which stimuli become or fail to become members of equivalence classes. Continued investigations of the role of compound stimuli in equivalence class formation may reveal further information regarding the necessary and sufficient conditions under which stimulus classes develop, as well as further elucidating the role of contiguity in the learning of symbolic stimulus relations.

## REFERENCES

- Dougher, M. J., & Markham, M. R. (1994). Stimulus equivalence, functional equivalence, and the transfer of function. In S. C. Hayes, L. J. Hayes, M. Sato, & K. Ono, (Eds.), *Behavior analysis of language and cognition* (pp. 71-90). Reno, NV: Context Press.
- Hayes, L. J. (1992). Equivalence as process. In S. C. Hayes & L. J. Hayes (Eds.), *Understanding verbal relations*. New York: Appleton
- Kamin, L. H. (1969). Predictability, surprise, attention, and conditioning. In B. A. Campbell & R. M. Church (Eds.), *Punishment and aversive behavior* (pp. 279-296). New York: Appleton-Century-Crofts.
- Markham, M. R., & Dougher, M. J. (1996). Compound stimuli in emergent stimulus relations: Extending the scope of stimulus equivalence. *Journal of the*

- Experimental Analysis of Behavior*, 60, 529-542.
- Sidman, M. (1971). Reading and auditory-visual equivalences. *Journal of Speech and Hearing Research*, 14, 5-13.
- Singh, N. N., & Solman, R. T. (1990). A stimulus control analysis of the picture-word problem in children who are mentally retarded: The blocking effect. *Journal of Applied Behavior Analysis*, 23, 525-532.
- Stickney, K. J., & Donahoe, J. W. (1983). Attenuation of blocking by a change in US locus. *Animal Learning and Behavior*, 11, 60-66.
- Stromer, R., McIlvane, W. J., & Serna, R. W. (1993). Complex stimulus control and equivalence. *The Psychological Record*, 43, 585-598.
- Stromer, R., & Stromer, J. B. (1990a). The formation of arbitrary stimulus classes in matching to complex samples. *The Psychological Record*, 40, 51-66.
- Stromer, R., & Stromer, J. B. (1990b). Matching to complex samples: Further study of arbitrary stimulus classes. *The Psychological Record*, 40, 505-516.
- Williams, B. A. (1975). The blocking of reinforcement control. *Journal of the Experimental Analysis of Behavior*, 24, 215-225.
- Williams, B. A., & Heyneman, N. (1983). Multiple determinants of "blocking" effects on operant behavior. *Animal Learning and Behavior*, 10, 72-76.