

BRIEF REPORT***ASSESSING TRANSFER OF RESPONSE SPEED AND NODALITY VIA
CONDITIONAL DISCRIMINATIONS***

Abdulrazaq A. Imam

JOHN CARROLL UNIVERSITY

What would happen if, having formed two independent sets of stimulus equivalence classes, one with a speed contingency and the other without, one member from the non-speed classes served as a positive comparison for a member of the speed classes? Would the remaining members of the non-speed classes occasion response speeds similar to those of the speed classes when tested? According to set union and intersection (Sidman, 1994), stimuli sharing membership in more than one class defined by different functions would exhibit overlapping characteristics. When sample-comparison choices between two speed and non-speed stimuli are trained, the non-speed stimulus acquires and shares overlapping response-speed characteristics with the speed stimulus, and might therefore transfer these properties to the remaining non-speed class members. What is unique about this arrangement is that transfer of the response-speed functions would have been achieved using conditional discrimination procedures exclusively.

In typical transfer-of-functions studies, upon demonstration of equivalence among class members, a new discriminative, response, or consequence function is trained to specific members of the class and then shown to transfer to the remaining class members (e.g., Barnes & Keenan, 1993; de Rose, McIlvane, Dube, Galpin, & Stoddard, 1988; Dymond & Barnes, 1994; Greenway, Dougher, & Wulfert, 1996). Besides training "a function that is independent of the

shared functions that define the class" (Dougher & Markham, 1996, p. 139), many such studies employ various nonmatching-to-sample procedures to train and/or test the independent function (e.g., Barnes & Keenan, 1993; Greenway et al., 1996). A study reported by Fields, Landon-Jimenez, Buffington, and Adams (1995) in which two five-member classes were formed is illustrative. The researchers trained four new responses to a subset of equivalence class members (A1, E1, A2, and E2 stimuli) using stimulus fading procedures, before testing for response transfer. They reported the formation of two five-member equivalence classes for two participants whose accuracy performances were inverse functions of nodality on post-transfer tests.

The post-transfer nodality effect suggests, of course, that the equivalence class members were not equally related to one another with respect to the new response function. Such evidence of nonsubstitutability of equivalence class members is problematic because by virtue of their class membership they should be substitutable for one another, ipso facto, due to their common history of reinforcement (Fields et al., 1995; Sidman, 1990, 1994; Sidman, Wynne, Maguire, & Barnes, 1989; cf. Fields, Adams, & Verhave, 1993). When new stimuli join a class by training or testing (Saunders, Saunders, Kirby, & Spradlin, 1988), therefore, the new members should become equivalent to the old ones (see Sidman, 1994, p. 543). Reports of nodality effects thus are unsettling from a reinforcement contingency perspective (Catania, 1996; Schick, 1971).

Imam (2001, Experiment 2) virtually eliminated the nodality effect by presenting equal numbers of baseline trial types, for participants who formed speed and non-speed equivalence classes. If, however, a member of a speed class served as a sample for a member of a non-speed class, would the other members of the non-speed

A faculty grant from the University Research Board of the American University of Beirut supported this research. Many thanks to Nidal Najjar for her diligent execution of the research protocols. The data were presented at the 1999 meeting of the Experimental Analysis of Behavior Group in London, England.

Address correspondence to A. A. Imam, Department of Psychology, John Carroll University, 20700 North Park Blvd., University Heights, OH 44118. E-mail: aimam@jcu.edu.

class exhibit response speeds similar to those of the speed class when tested? What would be the effect on nodality? The present study was designed to answer these questions.

No report of transfer of response speeds is available in the literature. Class expansions or mergers achieved by training new conditional discriminations between members of two existing equivalence classes have been reported, however (Saunders, Saunders, et al., 1988; Saunders, Wachter, & Spradlin, 1988; Sidman, Kirk, & Willson-Morris, 1985; see Green & Saunders, 1998). Sidman et al. (1985), for example, showed that training conditional discriminations with C and E stimuli from two separate three three-member classes (A, B, C, and D, E, F) resulted in six-member classes for five of eight participants (see also Saunders, Saunders, et al. 1988; Saunders, Wachter, & Spradlin, 1988). In a similar vein, if one could merge two sets of equivalence classes independently defined by sample-comparison selections with and without speed, it would forestall the need for new procedures and new functions commonly used in transfer-of-functions studies of substitutability that sometimes clutter the theoretical status of transfer of functions (for discussions see Dougher & Markham, 1994, 1996).

The present study trained and tested transfer of response speeds using only conditional discrimination tasks. A linear-series (LS) training structure typically employed in nodality tests (Imam, 2001; Saunders & Green, 1999) was used with equal numbers of baseline trial types to preclude the likelihood that the previously reported lack of nodality effect resulted from the extra FG trials presented in Imam (2001, Experiment 2). Thus, pre- and post-transfer tests should show no nodality effect.

METHOD

Subject and Apparatus

Dina was a female undergraduate of the American University of Beirut. She earned money based on hourly attendance and session performance, at a rate of LL. 4,500.00 (= U. S. \$3.00) per hour and LL. 31.00 (= U. S. \$0.02) per point earned regardless of feedback in a block.

A Macintosh computer controlled experimental events and collected data using MTS software (Dube & Hiris, 1997). Samples appeared at the center of the screen. Comparisons appeared randomly from trial to trial at the corners of the

screen. A click on the mouse button registered responses. The interval between responding to the sample and selecting a comparison defined latency. The experimenter calculated the response speed as the inverse of the latency.

Stimuli

Figure 1 shows the 2.5-cm by 2.5-cm stimuli used. The letter and number designations of comparison stimuli and class membership, respectively, were unknown to the participant.

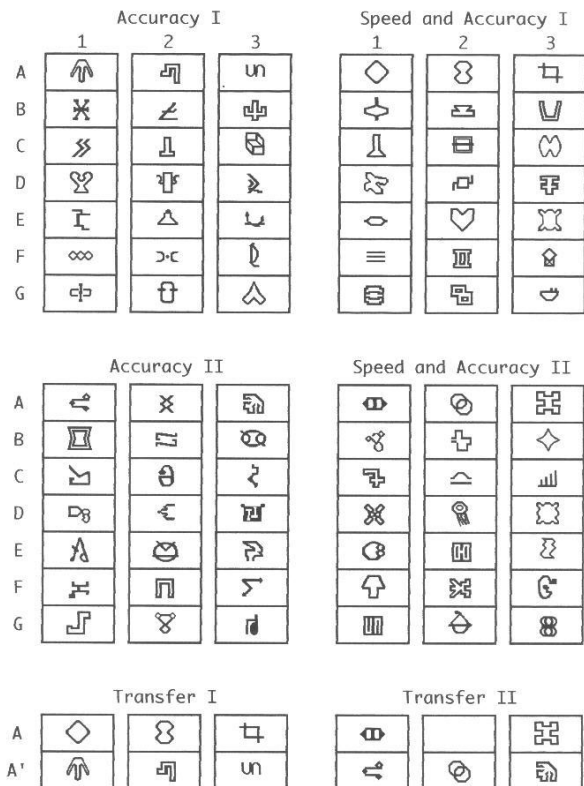


Figure1

General Procedures

Three stages were involved. The first stage established three seven-member classes in 4 conditions: Accuracy-1, Speed-and-Accuracy-1, Accuracy-2, and Speed-and-Accuracy-2. With the exception of Accuracy-1, each condition consisted of two consecutive phases: Paced and Massed. A unique set of stimuli was used in each of the four conditions (see Figure 1). Throughout, matching-to-sample procedures established conditional relations among the four different sets of stimuli. The general procedures, including matching-to-sample, pretraining, accuracy-only, and accuracy-

Table 1

Sequence of conditions and number of sessions for each condition.

Condition/Phase	Number of Sessions
Pretraining	1
Stage 1	
Accuracy 1 (Paced only)	8
Accuracy and Speed 1	
Paced	11
Massed	6
Accuracy 2	
Paced	5
Massed	3
Accuracy and Speed 2	
Paced	10
Massed	17
Stage 2: Review	5*
Stage 3: Transfer	4
Total number of sessions	70

* Review of Accuracy 1 was conducted twice.

and-speed contingencies, as well as the criteria for assessing the formation of equivalence classes, are detailed in Imam (2001, Experiment 2), and are not described further. Table 1 presents the sequence of conditions and the number of sessions per condition.

Stage 1: Demonstrating Equivalence Classes

Four sets of three seven-member equivalence classes were established in two accuracy-only conditions and two accuracy-and-speed conditions. Table 2 shows that each baseline trial appeared a minimum of 60 times by the end of paced training and testing (cf. Imam, 2001).

Paced Phase. Training alternated with testing blocks. Training blocks consisted of baseline trials designated AB, BC, CD, DE, EF, and FG. Testing blocks consisted of 24 1-, 2-, 3-, 4-, and 5-node transitivity (AC, AD, AE, AF, and AG), and equivalence (CA, DA, EA, FA, and GA) trials, respectively, in addition to the applicable baseline trials.

The first training block of AB and BC trials remained in effect until Dina attained at least 90% correct. To keep the number of trial types equal across the blocks of this phase, the number of AB+BC blocks completed determined the number of subsequent paced-training blocks. No

programmed consequences occurred in test blocks.

Massed Phase. Testing in the massed phase added the remaining equivalence and transitivity trial types to those tested in the paced phase and included symmetry tests in different blocks. The symmetry, transitivity, and equivalence blocks, presented in that order, contained their respective trial types plus the applicable baseline trials. No programmed consequences occurred in these test blocks.

Stage 2: Review of Stage-1 Classes

Because of the large number of sessions between the completion of the first and fourth conditions (see Table 1), a review of the four conditions of Stage 1 was conducted in two blocks each of symmetry, transitivity, and equivalence tests, to ensure maintenance of the conditional discriminations. Each test block was as described above for the massed phase. The Accuracy-1 review tests were repeated twice because no massed testing followed the first paced phase.

Stage 3: Transfer Training and Testing

Finally, two conditions of transfer-of-speed training and testing were implemented. As shown in the lower portion of Figure 1, in Transfer 1, the three A-stimuli of Speed-and- Accuracy-1 (A) served as samples for the three A-stimuli of Accuracy-1 (A'), using the former's 1.4-s limited hold. In Transfer 2, only A1 and A3 from Speed-and-Accuracy-2 served as samples for A1 and A3 of Accuracy-2, with a 1.3-s limited hold; A2 was always an incorrect comparison (see Figure 1). Each transfer-training block contained six trials of each trial type, making 18 trials in Transfer 1 and 12 trials in Transfer 2. Upon attaining a minimum of 90% correct in two consecutive training blocks with 100% feedback, transfer baseline maintenance blocks were presented without feedback before transfer testing resumed.

RESULTS

Dina formed four independent 3 seven-member equivalence classes and showed transfer of response speeds under the two transfer conditions.

Figure 2 presents the relative frequency distribution of response speeds for correct responses on equivalence trials under the accuracy-only (Accuracy), the speed-and-accuracy (Speed), and the transfer tests. The speed

Table 2

Minimum number of baseline relations presented in paced training and testing.

Block	Baseline Relation					
	AB	BC	CD	DE	EF	FG
Paced Training						
ABC	18	18				
ABCD	9	9	18			
ABCDE	6	6	15	21		
ABCDEF	3	3	3	12	27	
ABCDEFG	3	3	3	6	12	39
Subtotal	39	39	39	39	39	39
Paced Testing						
AC+CA	6	6				
AD+DA	6	6	9			
AE+EA	3	3	6	9		
AF+FA	3	3	3	6	12	
AG+GA	3	3	3	6	9	21
Subtotal	21	21	21	21	21	21
GRAND TOTAL	60	60	60	60	60	60

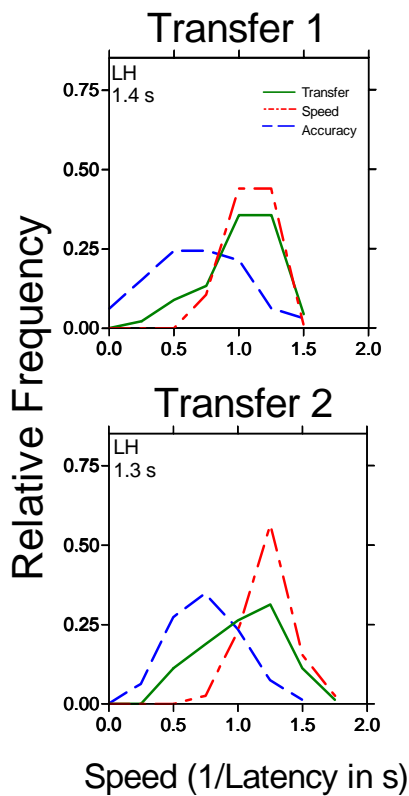


Figure 2

contingencies and transfer training produced skewed distributions of response speeds in the accuracy-and-speed and transfer tests, respectively, showing significant deviations from the normally distributed response speeds of the accuracy-only conditions. Incomplete transfer was indicated by the less leptokurtic distributions of the transfer speeds compared to those of the accuracy-and-speed.

Analyses of variance (ANOVA), conducted using GraphPad (2000) on mean response speeds of equivalence trials as a function of nodal number, assessed nodality in each condition across the three stages. Because each nodal number has unequal numbers of trial types in a LS structure, the number of 1-node, 2-node, and 3-node equivalence trials was equalized as described previously by Imam (2001) and Spencer and Chase (1996). In the paced phases, all trials in test blocks were included in the analyses. Figure 3 presents the mean response speed for correct responses at each nodal number for the paced, massed, review, and transfer phases (the two reviews of Accuracy 1 marked *). Error bars on the mean speed represent SD. Nine of the fourteen cases showed decreasing speed across nodal number, but only two of these (marked α in

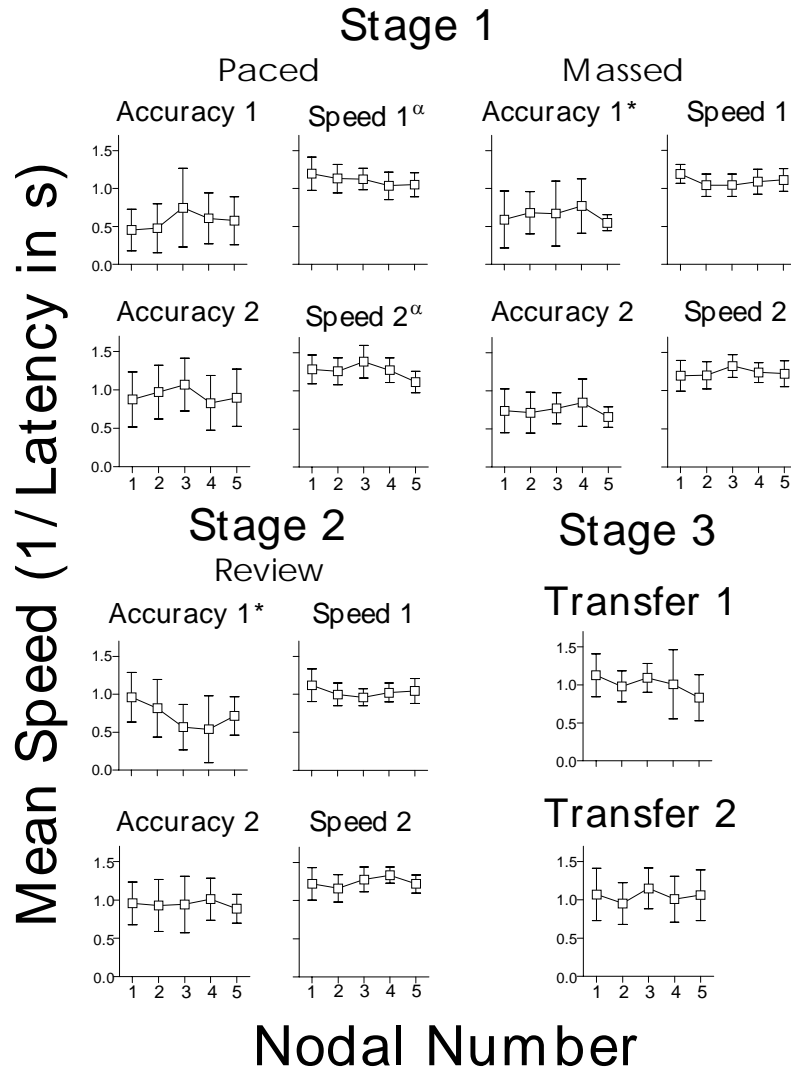


Figure 3

Figure 3) were statistically significant ($p < .05$). Both of these cases occurred under the speed conditions of the paced phase.

DISCUSSION

After conditional discrimination training, Dina responded faster under the two transfer conditions to non-speed equivalence class members previously not involved in transfer training. Dina’s performance demonstrated maintenance and merger of different equivalence classes by means of response-speed transfer through conditional discriminations. The increases in response speeds also indicated different degrees of mergers of class membership,

with Transfer 1 exhibiting better merger than Transfer 2 (see Figure 2), although neither showed complete merger. Such incomplete mergers may reflect Dougher and Markham’s (1996) observation that class unions do not automatically follow from the participation of stimuli in more than one class. Given that Dina received only one set of transfer testing blocks in the present study, it remains to be seen whether extended testing would yield a more complete merger than was found in the present study. Studies that have shown improved performance under continued testing during equivalence class formation (e.g., Saunders, Saunders, et al. 1988) suggest a similar

effect might occur under the present transfer model.

Despite the stringent contingencies in this experiment and the common difficulties of demonstrating equivalence under the LS structure (Fields et al., 1995; Saunders & Green, 1999), Dina formed four independent 3 seven-member classes representing four replications of Imam (2001). The results confirm those of Imam (2001, Experiment 2) in two specific ways. First, in the present experiment, across the paced, massed, and review phases, response speed changed in no systematic way as a function of nodal number, confirming the effects of presenting equal numbers of baseline conditional discriminations (cf. Imam, 2001, Experiment 1; Kennedy, 1991, Experiment 1; Spencer & Chase, 1996). Second, consistent with the pre-transfer results, the nodality effect was absent in post-transfer tests. Thus, in the present study, not only did the pre-transfer tests not show the nodality effect, the post-transfer tests failed to show it as well, precluding previous interpretations of the nodality effect observed in post-class-formation transfer tests but absent among pre-transfer class members (e.g., Fields et al., 1995).

Unlike in typical transfer-of-functions studies (e.g., Barnes & Keenan, 1993; de Rose et al., 1988; Dymond & Barnes, 1994; Fields, Adams, & Verhave, 1993; Fields et al., 1995; Greenway et al., 1996), no new and independent behavioral function was required to achieve the class mergers observed under the two transfer conditions of the present study. These results are consistent with set union and intersection (Sidman, 1994), which suggest that stimuli sharing membership in more than one class defined by different functions would exhibit overlapping characteristics. The results, therefore, support the feasibility of equivalence class mergers modeled after mathematical set union through exclusive use of conditional discrimination procedures. In this respect, this study represents an empirical first step towards a greater understanding of some of the clutter surrounding the theoretical status of transfer of functions (for discussions see Dougher & Markham, 1994, 1996).

REFERENCES

- Barnes, D., & Keenan, M. (1993). A transfer of functions through derived arbitrary and nonarbitrary stimulus relations. *Journal of the Experimental Analysis of Behavior*, **59**, 61-81.
- Catania, A. C. (1996). On the origins of behavior structure. In T. R. Zentall & P. M. Smeets (Eds.), *Stimulus class formation in humans and animals* (pp. 3-12). Amsterdam: Elsevier Science.
- de Rose, J. C., McIlvane, W. J., Dube, W. V., Galpin, V. C., & Stoddard, L. T. (1988). Emergent simple discrimination established by indirect relation to differential consequences. *Journal of the Experimental Analysis of Behavior*, **50**, 1-20.
- Dougher, M. J., & Markham, M. R. (1994). Stimulus equivalence, functional equivalence and the transfer of function. In S. C. Hayes, M. Sato, & K. Ono (Eds.), *Behavior analysis of language and cognition* (pp. 71-90). Reno, NV: Context Press.
- Dougher, M. J., & Markham, M. R. (1996). Stimulus classes and the untrained acquisition of stimulus functions. In T. R. Zentall & P. M. Smeets (Eds.), *Stimulus class formation in humans and animals* (pp. 137-154). Amsterdam: Elsevier Science.
- Dube, W., & Hiris, J. (1997). Match to Sample Program (Version 11.08a67) [Computer software]. Waltham, MA: E. K. Shriver Center for Mental Retardation.
- Dymond, S., & Barnes, D. (1994). A transfer of self-discrimination response functions through equivalence relations. *Journal of the Experimental Analysis of Behavior*, **62**, 251-267.
- Fields, L., Adams, B. J., & Verhave, T. (1993). The effects of equivalence class structure on test performance. *Psychological Record*, **43**, 697-712.
- Fields, L., Landon-Jimenez, D. V., Buffington, D. M., & Adams, B. J. (1995). Maintained nodal-distance effects in equivalence classes. *Journal of the Experimental Analysis of Behavior*, **64**, 129-145.
- GraphPad (2000). Prism for Windows (version 3.01) [Computer software]. San Diego, CA: GraphPad Software.
- Green, G., & Saunders, R. R. (1998). Stimulus equivalence. In K. A. Lattal & M. Perone (Eds.), *Handbook of research methods in human operant behavior* (pp. 229-262). New York: Plenum Press.
- Greenway, D. E., Dougher, M. J., & Wulfert, E. (1996). Transfer of consequential functions via stimulus equivalence: Generalization to

- different testing contexts. *Psychological Record*, **46**, 131-143.
- Imam, A. A. (2001). Speed contingencies, number of stimulus presentations, and the nodality effect in equivalence class formation. *Journal of the Experimental Analysis of Behavior*, **76**, 265-288.
- Kennedy, C. H. (1991). Equivalence class formation influenced by the number of nodes separating stimuli. *Behavioural Processes*, **24**, 219-245.
- Saunders, R. R., & Green, G. (1999). A discrimination analysis of training-structure effects on stimulus equivalence outcomes. *Journal of the Experimental Analysis of Behavior*, **72**, 117-137.
- Saunders, R. R., Saunders, K. J., Kirby, K. C., & Spradlin, J. E. (1988). The merger and development of equivalence classes by unreinforced conditional selection of comparison stimuli. *Journal of the Experimental Analysis of Behavior*, **50**, 145-162.
- Saunders, R. R., Wachter, J., & Spradlin, J. E. (1988). Establishing auditory stimulus control over an eight-member equivalence class via conditional discrimination procedures. *Journal of the Experimental Analysis of Behavior*, **49**, 95-115.
- Schick, K. (1971). Operants. *Journal of the Experimental Analysis of Behavior*, **15**, 413-423.
- Sidman, M. (1990). Equivalence relations: Where do they come from? In D. E. Blackman & H. Lejeune (Eds.), *Behavior analysis in theory and practice: Contributions and controversies* (93-114). Hove: Lawrence Erlbaum Associates Ltd.
- Sidman, M. (1994). *Equivalence relations and behavior: A research story*. Boston: Authors Cooperative.
- Sidman, M., Kirk, B., & Willson-Morris, M. (1985). Six member stimulus classes generated by conditional discrimination procedures. *Journal of the Experimental Analysis of Behavior*, **43**, 21-42.
- Sidman, M., Wynne, C. K., Maguire, R. W., & Barnes, T. (1989). Functional classes and equivalence relations. *Journal of the Experimental Analysis of Behavior*, **52**, 261-274.
- Spencer, T. J., & Chase, P. N. (1996). Speed analyses of stimulus equivalence. *Journal of the Experimental Analysis of Behavior*, **65**, 643-659.