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Go/No-Go Procedure with Compound Stimuli: Effects of Training Structure On the Emergence of Equivalence Classes

Priscila C. Grisante^{a,b}, Fernanda L. Galesi^c, Nathali M. Sabino^c, Paula Debert^{b,c}, Erik Arntzen^d, and William J. McIlvane^{b,e}

Priscila C. Grisante: prisgrisant@gmail.com; Fernanda L. Galesi: nanda_libardi@hotmail.com; Nathali M. Sabino: nathali@gmail.com; Paula Debert: pdebert@uol.com.br; Erik Arntzen: erik.arntzen@equivalence.net; William J. McIlvane: william.mcivane@umassmed.edu

^aUniversidade Federal de São Carlos

^bInstituto Nacional de Ciência e Tecnologia sobre Comportamento, Cognição e Ensino

^cUniversidade de São Paulo

^dOslo and Akershus University College

^eUniversity of Massachusetts Medical School

Abstract

When the matching-to-sample (MTS) procedure is used, different training structures imply differences in the successive discriminations required in training and test conditions. When the go/no-go procedure with compound stimuli is used, however, differences in training structures do not imply such differences. This study assessed whether the go/no-go procedure with compound stimuli with different training structures would produce significant variations in emergent performances. Fourteen undergraduate students were divided into two training groups: OTM and MTO (one-to-many and many-to-one). During training, responses emitted in the presence of compounds defined as related were reinforced. Responses emitted in the presence of compounds defined as not-related were not. During tests, new compounds structurally emulated MTS equivalence tests. All participants finished training with comparable number of sessions and 13 of 14 showed emergent performances. These results suggest that differences in equivalence-test outcomes with OTM and MTO training structures in MTS procedures may be due to their different successive discrimination requirements.

Keywords

go/no-go; compound stimuli; training structure; equivalence; human

To study formation of equivalence classes, the minimum prerequisites are (1) two conditional discriminations having elements in common (nodes) and (2) tests for emergent performances consistent with reflexivity, symmetry and transitivity (Sidman, 1994; Sidman & Tailby, 1982). The matching-to-sample (MTS) procedure is typically used in such studies. This procedure allows for different training structures, a term that refers to the assignment of sample and comparison functions to members of the stimulus sets during training (Fields, Adams, & Verhave, 1993; Saunders & Green, 1999). There are three possible structures with MTS training involving three stimulus sets (A, B and C): One-To-Many (OTM, sample as node; e.g., AB/AC), Many-To-One (MTO, comparison as node; e.g., AC/BC) and Linear Series (LS; AB/BC).

Although positive equivalence class formation outcomes are often quite robust and reliable in many studies, some have found different results with diverse participant populations that

have been attributed to different training structures: normally capable adults (e.g., Arntzen, Grondahl & Eilifsen, 2010; Arntzen & Hansen, in press; Arntzen & Holth, 1997, 2000; Fields, Hobbie-Reeve, Adams, & Reeve, 1999) individuals with intellectual disabilities (e.g., Saunders, Saunders, Williams, & Spradlin, 1993; Saunders, Wachter, & Spradlin, 1988; Spradlin & Saunders, 1986) and children (e.g., Arntzen & Nikolaisen, 2011; Arntzen & Vaidya, 2008; Saunders, Drake, & Spradlin, 1999). Why might different training structures lead to differences in equivalence class test outcomes?

Saunders and Green (1999) discussed the implications of earlier analyses of class structure influences by a number of other investigators (Saunders & Spradlin, 1993; Spradlin & Saunders, 1986; McIlvane & Dube, 1996; Sidman, 1994). Those analyses pointed out that between-sample discrimination in MTS procedures requires successive discrimination (i.e., sample stimuli are not simultaneously present) whereas between-comparison discrimination requires merely simultaneous discrimination (i.e., comparison stimuli are simultaneously present). Saunders and Green (1999) proposed that different training structure outcomes might be due to the degree to which a given training structure established the successive and simultaneous discriminations required on the equivalence test trials, as follows:

Many-to-one (MTO training AC/BC): accurate performance on training trials requires that stimuli from set C (comparisons) are discriminated simultaneously from each other as comparisons. The A and B stimuli (samples) must be discriminated successively. The test for equivalence (test AB/BA) calls for successive discriminations between each of the A and B stimuli across trials. Therefore, the MTO training structure requires the same successive discriminations during training as those required on the equivalence tests.

One-to-many (OTM training AB/AC): accurate performance on training trials requires that stimuli from sets B and C (comparisons) are discriminated simultaneously from each other. Only stimuli from set A (samples) must be discriminated successively during training. Although the BC/CB equivalence test calls for successive discriminations of both B and C stimuli, those discriminations are not required and may not be acquired during training. If they are not acquired, then the equivalence test outcomes should be negative, at least initially.

Linear Series (AB/BC training): accurate performance on training trials requires that stimuli from sets B and C (comparisons) are discriminated simultaneously from each other. Stimuli from sets A and B (samples) must be discriminated successively during training. The equivalence test AC/CA calls for successive discriminations of A and C stimuli. If successive discrimination of the C stimuli is not acquired during training, then certain equivalence test outcomes should be negative, at least initially.

To summarize, the MTO training structure requires all of the successive discriminations needed to achieve positive results on tests for transitivity and equivalence. The other training structures (OTM and LS) do not. Thus, it follows that the MTO structure may be more likely to lead to positive equivalence class outcomes than either the OTM or the LS structure. Results in the literature show some variability and occasionally contradictory findings. While the MTO structure has been generally regarded as the superior training structure when participants are individuals with intellectual disabilities, typically developing children (e.g. Fields et al., 1999; Saunders et al., 1999), the OTM structure seems to be superior when adults are participants (e.g., Arntzen & Holth, 1997; Arntzen et al., 2010).

Notably, the training structure analysis is not limited only to MTS procedures. There are other procedures that also lead to emergent behavior that is consistent with stimulus equivalence classes. One example is the go/no-go procedure with compound stimuli (Debert, Huziwara, Faggiani, Mathis, & McIlvane, 2009; Debert, Matos, & McIlvane, 2007; Perez,

Campos, & Debert, 2009). In the 2007 study, for example, each of the compound stimuli were two abstract black-and-white forms presented side-by-side in a single key at the center of a monitor screen. During the training phase, eighteen compound stimuli were successively presented. These included six that were designated as Related compounds (A1B1, A2B2, A3B3, B1C1, B2C2, and B3C3) and 12 designated as Not-Related compounds (A1B2, A1B3, A2B1, A2B3, A3B1, A3B2, B1C2, B1C3, B2C1, B2C3, B3C1, and B3C2). Following training, the components of each compound were recombined in new compounds corresponding to the tests employed symmetry (BA, CB), transitivity (AC) and equivalence (CA). All participants showed immediate emergence of behavioral relations consistent with symmetry, and five of six showed emergence of relations consistent with transitivity and equivalence.

The training structure employed in the 2007 study paralleled the Linear Series structure in MTS. However, unlike the MTS procedure, the go/no-go procedure requires that all of the compound stimuli and thus all of the elements that comprise them are discriminated successively. According to the analysis of Saunders and Green (1999), therefore, the training structures paralleling MTO, OTM, and Linear Series should have equivalent effects in the go/no-go procedure. If training structures differ reliably in their effects on go/no-go test outcomes, however, then the variables responsible for those differences would logically be other than those specified by Saunders and Green (1999). The present experiment compared the MTO and OTM training structures in the go/no-go compound stimulus procedure (the first training structure comparison with this procedure). We tested the prediction that these two training structures would have similar effects on outcomes for tests corresponding to symmetry and transitivity.

Method

Participants

Participants were 14 undergraduates who had no prior participation in behavior analysis research. Their participation provided them the opportunity to learn firsthand about research procedures and scientific questions and issues in this area during their post-participation debriefing. Participants were contacted in their classrooms. They signed a consent form and were informed that they could withdraw from the experiment at any time.

Apparatus

Sessions were conducted individually in a 3m × 3m room. Participants sat facing a portable computer running the *Windows*® operating system. Experimental tasks were controlled by software programmed in Visual Basic®. This software controlled the successive presentation of stimuli, recorded the mouse-click responses emitted by the participants, presented consequences for responses (points), and recorded experimental session's data.

Stimuli were the same geometrical shapes (black figures with a gray background - see Figure 1) as used in the studies by Debert et al. (2007), Markham and Dougher (1993) and Perez et al. (2009). Six figures (A1, A2, B1, B2, C1, and C2) were combined in pairs (compound stimulus) as shown in Figure 2.

Each compound stimulus was successively presented in a rectangle drawn on the center of the computer screen. Participants could click (or not) with the mouse inside this rectangle depending on the compound presented in each trial. In experimental sessions, stimuli were presented in a quasi-random sequence.

Procedure

The procedure had the following phases: training phase (Phase 1), symmetry test (Phase 2) and equivalence tests (Phase 3). Phases were identical for both the OTM and MTO groups, except for the training structure. Table 1 shows stimuli presented in training and test trials.

In each trial, compound stimuli (two figures presented side-by-side) were presented successively on the center of the screen. Each compound remained on screen for 4 s during training and symmetry tests phases. During equivalence tests, each compound remained on the screen for 8 s, a procedure suggested by results of Perez et al. (2009) to increase the likelihood that participants would respond to related test compounds. An intertrial interval (2 s) separated each trial, and responses within this period of time were not followed by programmed consequences.

Each trial presented one of two possible kinds of compound stimuli: Related compounds or Not-Related compounds. Related compounds were comprised of stimuli defined as members of the same stimulus class (e.g., A1B1, A2B2). Not-Related compounds were compounds comprised of stimuli defined as members of different classes (e.g., A1B2, A2B1). Participants were to respond to Related compounds by clicking them with the mouse and to do anything else when Not-related compounds were displayed. The sequence of trials was such that the Related or Not-Related compounds would not be repeated for more than three consecutive trials.

Phase 1 – Baseline Training—Phase 1 consisted of training AB/AC (OTM training structure) or AC/BC (MTO training structure) relations for different participants. Table 1 shows all the possible combinations of stimuli depending on the training structure used (OTM or MTO).

During sessions, each compound was presented once in a block of eight trials in a quasi-random order. This block was repeated 11 times (12 times in total). Thus, there were 96 trials in a training session. Ten points were delivered via a counter flashing for 1.5 s the upper left portion of the screen according to a CRF schedule for responses to Related compound stimuli in the first 12 trials. Thereafter, a conjunctive schedule used by Debert et al. (2007) was implemented (FR1 VT 2.5 s). Responses to the related compound stimuli only resulted in 10 points if the selected VT value has elapsed and if at least one response had occurred during this period. Responses emitted in the presence of Not-Related compound stimuli had no programmed consequences.

At the start of the experiment, an instruction was presented in Portuguese on the computer screen, as in Debert et al. (2007)' study. It translates as follows:

“This study is not about intelligence nor does it seek to assess your intellectual capabilities. You will receive further explanation about this at the end. I shall remain close by to resolve any technical problem that may arise with the equipment, but I shall not be able to speak with you. Your goal is to achieve the highest possible number of points. These points will be displayed in the upper left corner of the screen. Symbols will appear in an area defined in the center of the screen. Your task is to click on this area when the symbols you believe to be correct are displayed and not to click when the symbols are incorrect. At the beginning, you will earn points whenever you click on the correct symbols; subsequently, you will sometimes earn points, sometimes not. The task will become more difficult as time progresses. Therefore, pay attention even when the task seems very simple. Please repeat to me the instructions you have read”.

Baseline training ended when no errors occurred in a given session, that is, when the participant had responded at least once to all Related compounds presented and did not respond to all Not-Related compounds.

Phase 2 – Symmetry test—Compound stimuli were the same as those used in Phase 1, with the exception that their left-right position was reversed (see Table 1). Test trials were conducted in extinction, and sessions also had eight 12-trial blocks. Criterion was set at one session with two errors. The session was repeated if criterion was not met. The following instruction was given at the start of this phase:

“This is a new phase and your task will be modified. You should work according to what you have learnt. The points will no longer appear. When ready, click on OK”.

Phase 3 –Equivalence tests—The main difference procedurally in Phase 2 and this phase was the compounds presented: BC/CB to OTM group and AB/BA to MTO group (see Table 1). Criterion was 90% correct performance.

Results

Tables 2 and 3 show the percentage of correct responses during training and testing conditions for each participant. Percentage values were based upon the number of Related compounds to which at least one response was emitted plus the number of Not-Related compounds to which no responses were emitted divided by the total number of trials. Table 2 shows that training was completed from four to eight sessions for OTM participants and from three to nine sessions for MTO participants.

Table 3 shows that all participants for both OTM and MTO groups showed emergence of symmetric relations within one testing session. It shows also that seven MTO participants showed emergent equivalence relations within one (P8, P9, P10, P12, and P14) or two test sessions (P11 and P13). P11 and P13 did not respond to almost all compound stimuli in the first session and reached criterion on the second session (see Table 4). Six of seven participants from OTM group showed emergent equivalence relations (P2, P3, P4, P5, P6, and P7) in one test session. P1 (OTM) showed a simple discrimination pattern in two equivalence testing sessions in which only the related compounds B2C2 and C2B2 controlled responding. He did not respond to any other compound stimuli presented (see Table 4), and his test outcome was negative.

To summarize, both groups took a comparable number of sessions to reach criterion during training, all participants showed emergent relations consistent with symmetry, and 13 of 14 exhibited emergent relations consistent with equivalence relations within one or two test sessions.

Discussion

Our study evaluated whether different training structures (similar to OTM and MTO in MTS) using the go/no-go procedure with compound stimuli would have different outcomes on tests for symmetrical and transitive relations. The MTO structure resulted in five of seven positive outcomes in the first test session and two more in the second. The OTM structure resulted in six of seven positive outcomes, all in the first session. Overall, these results are very similar to those reported in prior studies using the Linear structure (e.g., Debert et al., 2007, 2009). Supporting an analysis consistent with that of Saunders and Green (1999), it appears that all three training structures have comparable effects, at least when employed in a go/no-go study with participants of the type studied here.

Why do different training structures sometimes appear to have different effects with procedures other than the go/no-go procedure studied here and sometimes not? One challenge in answering this question has to do with the many different procedures, test criteria, and populations that have been used. For example, we considered delayed emergence results of the type shown in our MTO group as positive outcomes as have others (e.g., Saunders et al., 1993), but this is not always the case (e.g., Arntzen et al., 2010). Some studies have used participants with developmental limitations who may require special training procedures to encourage successive discrimination (cf. K. Saunders & Spradlin, 1989, 1990), whereas others have studied participants such as ours who make successive discriminations readily. The population differences do not account for differential MTO/OTM outcomes, however, because they are demonstrable in typically developing adults (Arntzen et al., 2010; Hove, 2003).

Our data may help also to understand the behavioral processes involved in the phenomenon of gradual emergence of equivalence relations in repeated testing in extinction. Sidman (1990) suggested that such behavior results from a process analogous to hypothesis testing during responding to comparison stimuli that is required on forced-choice MTS tests. By contrast, go/no-go procedures do not force a choice between alternative comparison stimuli on symmetry and transitivity tests (i.e., the “choice” is merely to respond or not). Nevertheless, we have now obtained gradual emergence outcomes in both the present and past go/no-go studies. Clearly, gradual emergence does not depend upon the use of forced-choice MTS tests.

Although the results of the procedures comparison in our study and those of past go/no-go studies indicate comparability of outcomes on MTO, OTM, and Linear Series procedures, we are mindful that our studies have used fairly small, homogeneous samples. We anticipate questions about the fact that isolated failures have been obtained in OTM and Linear Series procedures and none as yet in the MTO procedure. For example, might one find that the MTO procedure has a small statistical superiority over the other two procedures in a larger sample? To answer this question, we used the present data in a power analysis, finding that we would have to run twice as many participants to obtain even a trivially small effect size (.2). Even if such positive results were obtained, they would be of very theoretical and practical importance. To detect medium to large effects, our power analysis indicated the need to study samples 5–10 times larger than the present one. Given that a large scale, very expensive study could be required to collect the data that only *might* detect a small statistical superiority of one procedure over the other, we think that this approach is unwarranted.

We think that better research directions for further assessment of the merits applying the Saunders and Green (1999) analysis to our go/no-go procedure would include (1) increasing the number of baseline and test relations to “stress” the relational learning capacity of participants from university-student samples (cf. Fields et al., 1999) and (2) including participants with developmental limitations (e.g., young children, older participants with intellectual disabilities) who have relatively greater difficulty in acquiring successive discriminations. If equivalence-test outcomes prove comparable also in such go/no-go studies, then the applicability of the Saunders and Green (1999) analysis to such procedures would show even more convincingly.

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Figure 1.
Stimuli used in the experiment. Each compound stimulus was formed by two of the figures presented, arranged side-by-side.

Figure 2.

Illustration of a trial. On the left is the monitor screen after the participants read the instructions and started the session and, on the right, is the monitor screen after a participant's response to a Related compound stimulus (A1C1).

Table 1

Compound stimuli presented in each experimental phase.

Phase 1- Training		Phase 2 – Symmetry tests		Phase 3 -Equivalence tests	
Related	Not-related	Related	Not-related	Related	Not-related
A1B1	A1B2	B1A1	B2A1	B1C1	B1C2
A2B2	A2B1	B2A2	B1A2	B2C2	B2C1
A1C1	A1C2	C1A1	C2A1	C1B1	C1B2
A2C2	A2C1	C2A2	C1A2	C2B2	C2B1
OTM					
Related	Not-related	Related	Not-related	Related	Not-related
A1C1	A1C2	C1A1	C1A2	A1B1	A1B2
A2C2	A2C1	C2A2	C2A1	A2B2	A2B1
B1C1	B1C2	C1B1	C1B2	B1A1	B1A2
B2C2	B2C1	C2B2	C2B1	B2A2	B2A1
MTO					
Related	Not-related	Related	Not-related	Related	Not-related
A1C1	A1C2	C1A1	C1A2	A1B1	A1B2
A2C2	A2C1	C2A2	C2A1	A2B2	A2B1
B1C1	B1C2	C1B1	C1B2	B1A1	B1A2
B2C2	B2C1	C2B2	C2B1	B2A2	B2A1

Table 2

Percentage of correct performances for each participant during training.

Session	OTM						
	P1	P2	P3	P4	P5	P6	P7
1	45.8 (44/96)	53.1 (51/96)	60.4 (58/96)	53.1 (51/96)	55.2 (53/96)	52.1 (50/96)	72.9 (70/96)
2	50 (48/96)	75 (72/96)	65.6 (63/96)	50 (48/96)	68.7 (66/96)	71.8 (69/96)	85.4 (82/96)
3	68.7 (66/96)	80.2 (77/96)	68.7 (66/96)	53.1 (51/96)	90.6 (87/96)	71.8 (69/96)	93.7 (90/96)
4	59.4 (57/96)	88.5 (85/96)	65.6 (66/96)	93.7 (90/96)	100 (96/96)	95.8 (92/96)	100 (96/96)
5	83.3 (80/96)	90.6 (87/96)	95.8 (92/96)	100 (96/96)		100 (96/96)	
6	87.5 (84/96)	100 (96/96)	97.9 (94/96)				
7	86.4 (83/96)						
8	100 (96/96)						

Session	MTO						
	P8	P9	P10	P11	P12	P13	P14
1	50 (48/96)	51 (49/96)	58.3 (56/96)	51 (49/96)	73.9 (71/96)	55.2 (53/96)	68.7 (66/96)
2	52.1 (50/96)	55.2 (53/96)	63.5 (61/96)	61.4 (59/96)	83.3 (80/96)	87.5 (84/96)	90.6 (87/96)
3	76 (73/96)	58.3 (56/96)	87.5 (84/96)	81.2 (78/96)	81.2 (78/96)	91.6 (88/96)	100 (96/96)
4	92.7 (89/96)	37.5 (36/96)	95.8 (92/96)	92.7 (89/96)	100 (96/96)	100 (96/96)	
5		44.8 (43/96)	86.4 (83/96)	100 (96/96)			
6		47.9 (46/96)	100 (96/96)				
7		79.1 (76/96)					
8		47.9 (46/96)					
9		98.9 (95/96)					

Table 3

Percentage of correct performances for each participant during testing.

Part.	OTM			MTO		
	Symmetry		Part.	Equivalence		Equivalence
	Ses 1	Ses 2		Ses 1	Ses 2	
P1	100* (96/96)	73.9 (71/96)	P8	97.9 (94/96)	94.8 (91/96)	
P2	100 (96/96)	100 (96/96)	P9	100 (96/96)	100 (96/96)	
P3	100 (96/96)	100 (96/96)	P10	97.9 (94/96)	92.7 (89/96)	
P4	100* (96/96)	97.9 (94/96)	P11	97.9 (94/96)	48.9 (47/96)	96.9 (93/96)
P5	100 (96/96)	100 (96/96)	P12	97.9* (94/96)	97.9 (94/96)	
P6	98.6 (95/96)	96.9 (93/96)	P13	98.6 (95/96)	59.4 (57/96)	97.7 (94/96)
P7	98.6 (95/96)	92.7 (89/96)	P14	100 (96/96)	100 (96/96)	

Note. Asterisk (*) indicates that there was a two-day interval between sessions. So, a previous phase session was conducted before tests. In all cases, criterion was achieved in one session.

Table 4
Percentage of responses to each compound during each session of equivalence tests for Participants P1, P9 and P13.

Compound	P1		Compound	P9		P13	
	Session 1	Session 2		Session 1	Session 2	Session 1	Session 2
B1C1	0 (0/12)	0 (0/12)	A1B1	17 (2/12)	100 (12/12)	0 (0/12)	100 (12/12)
B2C2	100 (12/12)	100 (12/12)	A2B2	0 (0/12)	92 (11/12)	41 (5/12)	83 (10/12)
C1B1	0 (0/12)	0 (0/12)	B1A1	17 (2/12)	100 (12/12)	0 (0/12)	100 (12/12)
C2B2	92 (11/12)	100 (12/12)	B2A2	0 (0/12)	92 (11/12)	33 (4/12)	100 (12/12)
B1C2	0 (0/12)	0 (0/12)	A1B2	33 (4/12)	0 (0/12)	0 (0/12)	0 (0/12)
B2C1	0 (0/12)	0 (0/12)	A2B1	0 (0/12)	8 (1/12)	0 (0/12)	0 (0/12)
C1B2	0 (0/12)	0 (0/12)	B1A2	0 (0/12)	0 (0/12)	0 (0/12)	0 (0/12)
C2B1	0 (0/12)	0 (0/12)	B2A1	8 (1/12)	0 (0/12)	0 (0/12)	0 (0/12)