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The Effect of Pre-training of Abstract Stimuli to Exert Control over Tact and Mand Responses on Stimulus Equivalence Class Formation

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Abstract

Recent studies show that the formation of stimulus equivalence classes can be enhanced by meaningful stimuli. The purpose of this study was to investigate whether acquired meaningfulness, through pre-training of meaningless stimuli to exert control over tact or mand responses, would enhance stimulus equivalence class formation. Participants were eighteen university students aging 18-over 40 that were alternately assigned to either the Tact (*n*= 9) or the Mand Group (*n*= 9). Participants in all groups received a card sorting test following either a tact or mand pre-training. They then received training and testing procedures to establish three 3-node 5-member equivalence classes under the simultaneous protocol. After serialized training of AB, BC, CD, and DE relations, all probes used to assess the emergence of symmetrical, transitive, and equivalence relations were presented for two test blocks. Lastly, the card sorting procedure was repeated. Results showed that the pre-training of abstract stimuli to exert control over tact and mand responses did not produce equivalence class enhancement. Future studies should further investigate the relationship between the verbal properties of meaningful stimuli and the formation of stimulus equivalence classes.
Keywords:stimulus equivalence, meaningful stimuli, tact pre-training, mand pre-training.

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Novelty and Significance

What is already known about the topic?

- The human ability of understanding and using symbols (such as labels) is quite documented in the behavior analysis literature.
- Research shows that the ability of understanding of symbols is enhanced by certain types of stimulus pre-training.
- Stimuli features accounting for meaning may be represented by their acquired behavioral functions, such as discriminative, conditional, eliciting functions, among others.

What this paper adds?

- The factors involved in the history of a given event becoming meaningful are not fully understood.
- It is currently unknown whether events become meaningful after they acquire the property of producing verbal responses, such as labeling things and asking for things.
- It is not clear whether events with an acquired history of producing verbal responses facilitate the development of behaviors related to the understanding of symbols.

The formation of stimulus equivalence classes is a type of emergent behavior that is observed during behavioral tests in which untrained conditional discriminations meet criteria of reflexivity, symmetry, and transitivity after some conditional discriminations are directly trained (Sidman & Tailby, 1982).

From a theoretical perspective, the stimulus equivalence approach has provided a solid basis for the behavioral-oriented understanding of the learning of symbols (Bortoloti & de Rose, 2012). Experimentally, it has strongly supported the description,

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prediction, and control of symbolic behaviors since the Sidman's 1971 classical study. And, with regard to the applied field, a number of stimulus-equivalence-based teaching procedures has been successfully used to teach a wide range of academic skills such as such as reading (De Rose, Souza, & Hanna, 1996), writing (Stromer & Mackay, 1993), statistics (Critchfield & Fienup, 2010; Fields, Travis, Roy, Yadlovker, Aguiar-Rocha, & Sturmey, 2009), manual signs (Elias, Goyos, Saunders, & Saunders, 2008), mathematics skills (Lynch & Cuvo, 1995), braille literacy skills (Toussaint & Tiger, 2010), and brain-behavior relations (Fienup, Covey, & Critchfield, 2010).

Another topic of major research interest within behavior analysis is the study of meaning. It has been behaviorally defined in terms of the stimulus properties that come to exert functional control over respondent, operant or relational responses (e.g., Arntzen & Mensah, 2020; Nedelcu, Fields, & Arntzen, 2015). Almeida and de Rose (2015) have proposed an alternative approach to a behavioral description of meaning that focuses on the strengthening of one or more dimensions of a previously neutral stimulus, such as valence.

Of special interest to this paper is the line of investigation within the stimulus equivalence research devoted to the study of the relationship between stimulus meaningfulness and equivalence class formation. A series of experiments in this field has shown that stimuli with an acquired-meaningfulness history may produce equivalence class enhancement (Fields & Arntzen, 2018).

Those studies demonstrated that the meaningfulness of a given stimulus: (1) can be arranged experimentally and (2) can be functionally described in terms of controlling properties of the stimulus. Thus, it is plausible to assume that a stimulus could become meaningful through an acquired history of stimulus control over verbal operants (Skinner, 1957). In this case, a reasonable question to ask would be whether stimuli experimentally manipulated in such a way would produce equivalence class enhancement.

According to Skinner (1957), tact responses are emitted under discriminative control of a nonverbal stimulus, that is, "(…) the whole of the physical environment – the world of things and events which a speaker is said to talk about" (p. 81), and are followed by generalized reinforcers, which are reinforcers established and maintained via relations with two or more reinforcers (Skinner, 1953). For example, a child is presented with a doll, she says "doll", and this response is reinforced with praise, such as "well done!". Mand responses are emitted under functional control of relevant conditions of deprivation or aversive events and are followed by specific reinforcers. For example, a child is thirsty, she says "could you please give me some water?", this response is reinforced through someone who will give her water, which is the specific reinforcer.

The facilitating role of tacts and mands in the production of emergent behavior has been investigated in many studies. In their classic 1996 paper, Horne and Lowe proposed that tact repertoires (i.e., speaker behaviors), along with listener repertoires, enable the establishment of naming, a type of emergent behavior that is closely related to the development of human language, according to their approach.

Following that, Miguel *et alia* (2008) investigated whether speaker (i.e., tact repertoires) and listener behaviors would increase the participants' performance in stimulus categorization tasks, a measure of emergent relational responding. The authors found that both listener and speaker behaviors are important in producing stimulus categorization; moreover, they observed that when participants failed in the sorting test, they also failed to tact accurately.

In a study comparing mand-tact training (1) and tact-only training (2), Arntzen and Almås (2002) encountered that, on average, fewer trials were needed in condition 1 to establish both mands and tacts while condition 2 established only tacts in about the same number of trials. These results suggest a facilitating role of the combined mand training to establish both tact and mand repertoires. Along this line, Nuzzolo Gómez and Greer (2004) observed the emergence of tact and mand responses through a history with multiple exemplar training.

Although the relationship between mands and tacts and emergent behavior has been investigated in many studies, up to date, their equivalence class enhancing properties are unknown (Fields & Arntzen, 2018).

On one hand, data on this subject would give strength to the functional description of stimulus meaningfulness (Almeida & de Rose, 2015; Arntzen, Nartey, & Fields, 2015). On the other hand, this could support the view that stimuli controlling elementary verbal operants may become meaningful on the basis of whether they occasion verbal responses.

Thus, the purpose of this study was to investigate whether acquired meaningfulness would produce an effect in stimulus equivalence class formation. Hence, the participants went through a pre-training of meaningless stimuli to exert control over tact or mand responses.

Method

Participants

Participants were eighteen university students aging 18 to over 40 (see Table 1). All participants except three had participated in stimulus equivalence experiments prior to this study, however, the studies they participated in were different from the present one in that those studies investigated other types of pre-training, for example, conditional discrimination, overtraining, and nodal structure, whereas the present study focuses on verbal operants. Some of the participants were recruited from the same course, which increased the chances that they knew one another. The participants were given the consent form containing detailed information about the study upon entering the experimental

Table 1 Participant background information

Participant		Sex	Age range	University Education	Prior participation in stimulus equivalence experiments
Tact Group	P1	F	25-29	4	Yes
	P3	F	40 +	2	Yes
	P5	M	40 +	5	No
	P7	F	35–39	2	Yes
	P9	F	18–24	1	Yes
	P11	M	40 +	5	Yes
	P13	F	30–34	1	Yes
	P15	F	40 +	2,5	Yes
	P17	F	30–34	7	No
Mand Group	P2	F	18–24	0	Yes
	P4	F	18–24	1	Yes
	P6	F	18–24	1	Yes
	P8	F	18–24	1	No
	P10	F	25–29	2	Yes
	P12	M	25–29	1	Yes
	P14	F	18–24	1	Yes
	P16	F	18–24	1,5	Yes
	P18	F	40 +	3	Yes

room. They were also given a background questionnaire asking information about gender, age range, years completed of university education, course, and whether the participant had any prior experience with stimulus equivalence procedures and behavior analysis, for example, through courses or research. The participants were fully debriefed after they had completed the experimental session, that is, the participants were given information about the purpose and the procedures of the study. The participants also received information about their own performance during the training and the tests. All procedures performed in studies involving human participants were in accordance with the ethical standards and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Design

A between-groups experimental design was used. The participants were alternately assigned to one of two experimental groups: tact pre-training (*n*= 9) or mand pre-training (*n*= 9). For assigning participants to one of the two conditions, the experimenter made a participant recruitment list and assigned participants to one of the two groups alternately at the time that they scheduled a session with the experimenter.

Apparatus

Setting. The experiment was conducted at three different campuses of Oslo Metropolitan University. Sessions carried out at the main campus occurred either in a two-room experimental laboratory containing a greeting room and an experimental room containing two experimental cubicles or in a one-room tracking system laboratory, equipped with four tables, one tabletop computer, and five chairs. In this latter laboratory, the room lights were dimmed (half of them were off) due to other experiments taking place at the same time using the tracking system. In this case, a portable light bulb was placed in the room for the experimental sessions. Sessions carried out either at the other two campus' occurred in group rooms containing a few chairs, a table, and a white board.

Hardware. A Compaq nc6320 laptop computer running Windows 10 and screen size measuring 16.8-in diagonal length with a 16 3 9 horizontal-to-vertical ratio was used along with an external mouse.

Software. The training and testing sessions for conditional discriminations for all the participants were conducted with a customized matching-to-sample (MTS) software. The software controlled the stimulus presentation format, recorded responses considering the following parameters: trial number, number of training trials, correct and incorrect responses, programmed consequences. The software also provided a report summarizing the following information: directly trained trials or baseline trials, symmetry trials, transitivity trials, and equivalence trials as well as the exact duration of the experiment.

Stimuli

The experiment used abstract (members of A, B, D, and E stimulus classes) and meaningful stimuli (members of C stimulus class) as members of equivalence classes. Figure 1 displays 15 abstract shapes that were used as abstract stimuli (A1, A2, A3, B1, B2, B3, D1, D2, D3, E1, E2, and E3). C1, C2, and C3 were three abstract shapes that were chosen by the experimenter to carry out the procedures through which they would become meaningful stimuli, that is, the tact or the mand pre-training. C stimuli were used in the the tact and the mand pre-training following the line of research showing that meaningful stimuli used as C stimuli increases the probability of producing stimulus equivalence class formation (Mensah & Arntzen, 2016). All stimuli were displayed in black color against a white background. The size of each stimulus displayed on the

Figure 1. Stimuli used as members of the stimulus equivalence classes.

computer monitor was 9.4cm×3.4cm.

Procedure

General procedures. Participants in all groups received a card sorting test initially. Next, they received either tact or mand pre-training according to the group they were assigned to. They then received training and testing procedures to establish three 3-node 5-member equivalence classes under the simultaneous protocol. After serialized training of AB, BC, CD, and DE relations, all probes used to assess the emergence of symmetrical, transitive, and equivalence relations were presented for two test blocks. Lastly, the card sorting procedure was repeated. The experiment was carried out individually and lasted two hours on average.

Card Sorting. Participants were given 15 flashcards sized 8x8cm with the abstract stimuli individually printed on each of them. Next, the experimenter placed the flashcards on the table and guideless mixed them in front of the participant. The participant was then asked to put them in groups. The card sorting procedure was done before the participant went through the tact/mand pre-training and the stimulus-equivalence training and testing procedures. The card sorting was done in the same manner for each participant and for both tests -prior and after the tests for stimulus equivalence. The purpose of this was to rule out the possibility that the participant demonstrated experimenter-defined classes prior to the experiment. The experimenter took a picture of the card arrangement produced by the participant and the data were then transferred to a datasheet. Target responses were the stimulus classes that the participants established prior and after the stimulus equivalence tests.

Reinforcer Selection Procedure. The participants in the mand pre-training group received specific reinforcers for their mand responses. In order to select potential reinforcers, each participant was presented with nine 3x3cm colored pictures of snacks. Next, the following instruction was provided: “In your next activity, you will be asked to make requests. For this, you will use pictures of actual snacks that you will be able to take home. Please choose three of them you would like to get the most". The participant then handed the pictures of the snacks of their choice to the experimenter. The actual snacks items were then placed on a table located in front of them and the mand pre-training procedure started immediately following that. The experimenter recorded the snack choices of each participant in a datasheet. The target responses were the participants snack choices.

Mand Pre-training. For the mand pre-training, each of the three snacks that were chosen by the participant during the reinforcer selection procedure was arbitrarily assigned to either C1, C2, or C3 stimuli (i.e., C1/snack 1, C2/snack 2, C3/snack 3. Note that snacks 1, 2, and 3 varied for each participant). At the beginning of the mand pre-training, the participant was handed individual 3x3cm black-and-white pictures of C1, C2, and C3 stimuli; in addition, three 3x3cm colored pictures of each of the snacks were placed at the table along with the datasheet. Next, the experimenter held the pictures of snacks 1, 2 and 3, and provided the following instruction: "You will make requests using those pictures that were handed to you. For each correct response, you will be given a picture of a snack item. When you get all responses correct, the snack items you chose will become available for you to take home". In each mand pre-training trial, the experimenter showed a picture of a snack and said: "I have this. You can get it by making a request". Mand responses for exchanging C1 for the picture of the snack 1 (i.e. I want to exchange C1 for snack 1) were followed by the delivery of the requested snack item picture. Likewise, mand responses for exchanging C2 and C3 for snack items 2 and 3, respectively, were followed by the requested items. Incorrect mand responses were followed by "No" and a 2s-timeout period. There were three trials for each stimulus pair (C1/snack 1, C2/snack 2, C3/snack 3) and the stimulus presentation was balanced out across 9 trials. Accuracy criterion was 100% correct responses across 9 consecutive trials. Mand responses were recorded manually using a datasheet.

Tact Pre-training. In each trial, the participant was presented with one of the C stimuli and were asked "What is this?" Correct tact responses (say "Paf" in the presence of C1, "Zog" in the presence of C2, and "Vek" in the presence of C3) were followed by praise ("Good!") and incorrect responses were followed by corrective programmed consequence ("Say [Cn]"). There were three trials for each C stimuli and the stimulus presentation was balanced out across 9 trials. Accuracy criterion was 100% correct responses across 9 consecutive trials. Tact responses were recorded manually using a datasheet.

Stimulus Equivalence Procedures

Trial Structure and Contingencies. Each trial began with the presentation of the sample stimulus at the middle of the computer screen. Clicking the sample stimulus was followed by the presentation of three comparison stimuli displayed at three of the four corners of the computer screen, while the sample stimulus was still displayed at the middle of the computer screen. The location of the comparison stimuli throughout the trials was randomized. Clicking one of the comparison stimuli was followed by programmed consequences (i.e., a written word, such as "correct" was the programmed consequence for correct responses and a written word such as "wrong" was the programmed consequence for incorrect responses) that were displayed in the middle of the computer screen for 1,000 ms and followed with a 500-ms intertrial interval. Between the trials, the mouse cursor was reset to the middle of the screen. The target responses during the training and testing procedures were the selection of the experimenter-defined correct comparison stimuli.

Computer instruction. Immediately after the pre-training sessions, the participant was seated in front of the computer and was presented with the following instruction, delivered through the computer screen:

> "In a moment, a stimulus will appear in the middle of the screen. Click on this by using the computer mouse. Three stimuli will then appear in the three corners of the screen. Choose one of them by clicking on it with the mouse. If you choose the stimulus we have defined as correct, words like "very good", "excellent",

and so on will appear on the screen. If you press a wrong stimulus, the word "wrong" will appear on the screen. At the bottom of the screen, the number of correct responses you have made will be counted. During some stages of the experiment, the computer will NOT tell you if your choices are correct or wrong. However, based on what you have learned so far, you can get all of the tasks correct. Please do your best to get everything right. Thank you and good luck!"

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Acquisition of baseline relations. Baseline involved the sequential training of AB, BC, CD, and DE relations in 9-trial blocks. In each block, each trial type was presented three times and trials were balanced out within a block. (see Table 2 for a full overview of each of the experimental phases). Programmed consequences were provided for comparison selections on every trial. For each relation, a mastery criterion of 100% correct responses was in effect and the participants received 9-trial blocks until the criterion was met. Next, they received a mixed training in blocks of 36 trials containing all baseline relations (i.e., AB/BC/CD/DE). A mastery criterion of 100% correct responses was set and the mixed training was carried out until the criterion was met.

Reduction of programmed consequences. The participants received mixed training in blocks of 36 trials as previously described; however, programmed consequences were reduced to 75%, 50%, and 0%, respectively. The criterion for reduction of programmed consequences was set at 100% correct responses within a block at each level of programmed consequences. Reduction of programmed consequences were carried out until 100% correct responses was achieved within a block with no programmed

Table 2. Summary of Experimental Sequence.

Experimental sequence	Trial type	% Programmed Consequence	Number of trials
Serialized trials	A1B1,A2B2, A3B3 B1C1, B2C2, B3C3 C1D1,C2D2, C3D3 D1E1, D2E2, D3E3	100	9
Mixed trials	A1B1,A2B2, A3B3 B1C1, B2C2, B3C3 C1D1,C2D2, C3D3 D1E1, D2E2, D3E3	100	36
Reduction of programmed consequences	A1B1,A2B2, A3B3 B1C1, B2C2, B3C3 C1D1,C2D2, C3D3 D1E1, D2E2, D3E3	100	36
	A1B1,A2B2, A3B3 B1C1, B2C2, B3C3 C1D1,C2D2, C3D3 D1E1, D2E2, D3E3	50	36
Test for emergent relations	A1B1,A2B2, A3B3 B1C1, B2C2, B3C3 C1D1,C2D2, C3D3 D1E1, D2E2, D3E3	0	36
Baseline trials	A1B1,A2B2,A3B3, B1C1,B2C2, B3C3, C1D1,C2D2,C3D3, D1E1, D2E2, D3E3	0	36
Symmetry trials	B1A1,B2A2,B3A3, C1B1,C2B2, C3B3, D1C1,D2C2,D3C3, E1D1, E2D2, E3D3	0	36
Transitivity trials	A1C1,A2C2,A3C3, A1D1,B1D1,A2D2, B2D2,A3D3,B3D3, A1E1,B1E1, C1E1, A2E2,B2E2, C2E2, A3E3, B3E3, C3E3	0	54
Equivalence trials	C1A1,D1A1,E1A1, C2A2,D2A2,E2A2, C3A3,D3A3,E3A3, D1B1,E1B1, D2B2, E2B2,D3B3, E3B3, E1C1, E2C2, E3C3	0	54

consequences.

Tests for Emergent Relations. The participants were presented with a test block for immediate and delayed emergent relations that contained 180 trials. Of the 180 trials, there were 36 baseline trials, 36 symmetry trials, 54 transitivity, and 54 equivalence trials. There were no programmed consequences during the tests for emergent relations. The formation of equivalence classes was defined by the selection of class-consistent comparisons on at least 90% of the trials for each type of relation.

RESULTS

The present experiment studied the effect of pre-training of meaningless stimuli to exert control over tact or mand responses (acquired meaningfulness) on stimulus equivalence class formation. In the following, we describe data on group performances in tests for stimulus equivalence class formation, card sorting, number of blocks needed to acquire baseline relations, number of tact/mand pre-training sessions to criterion, and reinforcer selection.

Table 3 shows the number of trials to criterion, and number of correct and incorrect responses of participants that received the mand pre-training condition. A minimum of one and a maximum of five trials were needed for participants to achieve criterion during the mand pre-training. Data for each participant varied in terms of the total number of correct and incorrect responses.

Figure 2 shows the percentage of correct responses of both tact and mand groups during the tests for stimulus equivalence class formation. The upper graphic shows data of participants meeting criterion (equal or above 90% correct responses) and the lower graphic shows data of those who did not meet criterion for stimulus equivalence class formation. Correct responses were defined by responses consistent with experimenter-

Table 3. Results of card sorting before and after tests for stimulus equivalence class formation in both Tact and Mand groups.

Group	Participant	Meeting criterion	
		Pre-class formation	Post-class formation
Tact	P5	A1A3B2E1B1B3C3, A2D2D1D3C1E3C2E2	B3E1D2A2, E2D1C3D3E3, B2A1B1, A3C3C1
	P13	A2A3D2, E1, B2B3C3C1B1A1, D3E3E2D3C2	D1C2E2C1D3E3, A2A3D2, C3B3B2B1A1E1
Mand	P10	A2C1C3D2A3, D1C2D3E2E3, B2E1B3A1B1	**B3A3D3C3E3, A2B2C2D2E2, E1D1A1B1C1**
		Not meeting criterion	
Tact	P9	A1C3C1, B1E1B2, D2A3D1A2, E2D3D1	C2B3A3D1D2, A2E3C3B2D3, **C1B1A1E1D1**
	P11	E1, B2D3, A1B1E3C2D1E2, C3A3C1A2D2B3	**D2C2B2A2, E3D3C3**, E2B3A3, **C1B1A1, D1E1**
	P15	B2E1, B3B1, C1A1, D1E2, **C3A3**, E3C2D3, A2D2	C2D2E2A3B3, **B1A1D1C1E1**, D3E3A2B2C3
	P17	D1C2E1, B2B1B3, **C3A3**, A1A2, C1E2D3E3D2	C1B3D1A3E1, D3A1E3B1C3, **B2A2C2D2E2**
Mand	P8	B2B3E1B1, A2D1D2, C3A3A1, D3C2, C1E3E2	A2B2E1, **C3D3E3B3A3**, A1B1E2C1
	P12	**D3C3E3**, B3A2C3A3, B2, E1E2D1, C1A1D2B1	D3B1A1, **C2B2A2**, **E3B3A3, C2B2A2**, E1D2D1, E2C1C3
	P14	A1C3A2A3, E1D3B2B3B1, E3E2D1C1C2D2	C3C2A2D3E3E2, **D2B2**, A3D1E1B3B1C1A1
	P16	C1D3, B1B2, E1A1, E3C2, A2B3D2, **A3C3**, D1E2	**A3B3C3, B1C1A1**, D3E3E1,**E2D2C2**, B2A2D1

Notes: Data for three participants in the tact group and four in the Mand Group are not available due to technical issues (the experimenter took pictures of the categorization tests for each participant, but the corresponding picture files were accidentally deleted). The capitalized letters represent stimuli in each class (i.e., A, B, C, D, and E) and the numbers represent the members in each class (i.e., A1, A2, and A3 are members of the stimulus class A). Data sets in bold represent partial class formation, that is, the formation of stimulus classes that included some, but not all of the members belonging to the same formed stimulus class (i.e., A1B1C1D1E1).

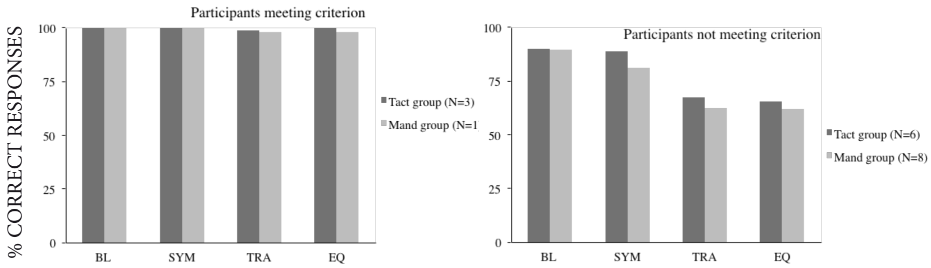

Figure 2. Percentage of correct responses during tests for stimulus equivalence classes in both tact and mand groups. BL, SYM, TRA, and EQ represent the performances of each group (Tact or Mand Group) during baseline, symmetry, transitivity, and equivalence tests, consecutively.

defined comparison selections.

The percentage of correct responses during tests involving baseline, symmetry, transitivity, and equivalence relations for the tact group meeting criterion was 100%, 100%, 99%, 100%, and for the mand group it was 100%, 100%, 98.1%, and 98.1%, respectively. The same data for the tact and mand groups not meeting criterion were, 90.2%, 88.8%, 67.5%, 65.7%, and 89.5%, 81.4%, 62.5%, 62.2%, respectively.

Figure 3 shows the average number of blocks needed to acquisition of baseline relations for both tact and mand groups. Again, the upper graphic shows data of participants meeting criterion and the lower graphic shows data of those who did not

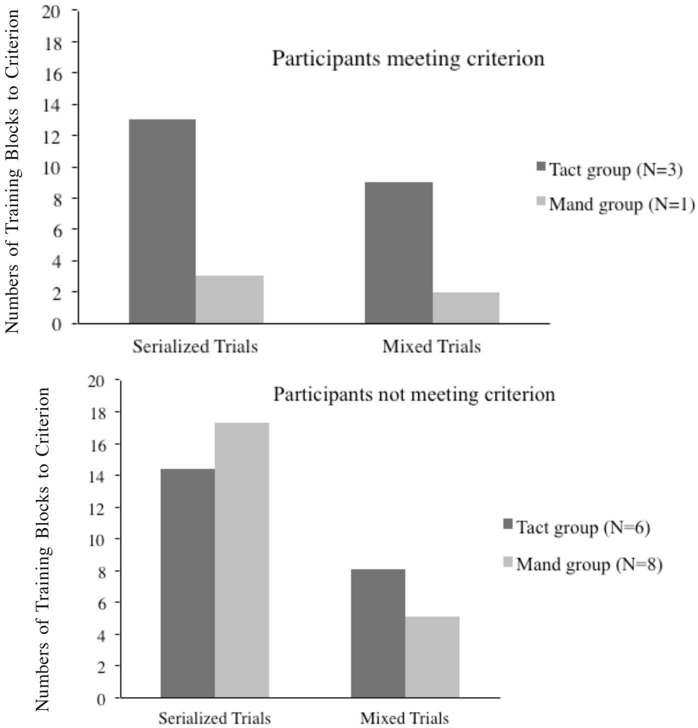

Figure 3. Average number of training blocks to criterion in both tact and mand groups.

meet criterion for stimulus equivalence class formation. The average number of blocks of 9 serialized trials for the tact and mand groups meeting criterion was 13 and 3, respectively, and for those not meeting criterion the averages were 14.4 and 17.3. For blocks of 36 mixed trials, the averages for the tact and mand groups meeting criterion were 9 and 2, respectively, and for those not meeting criterion the averages were 8,1 and 5,1.

Figure 4 shows data on reinforcer selection for participants in the mand group. Each participant in this group was given the option of choosing three items of their choice for the mand pre-training. The bars indicate the overall number of times each of the items was selected. As shown the yogurt was the top ranked and the bread spread

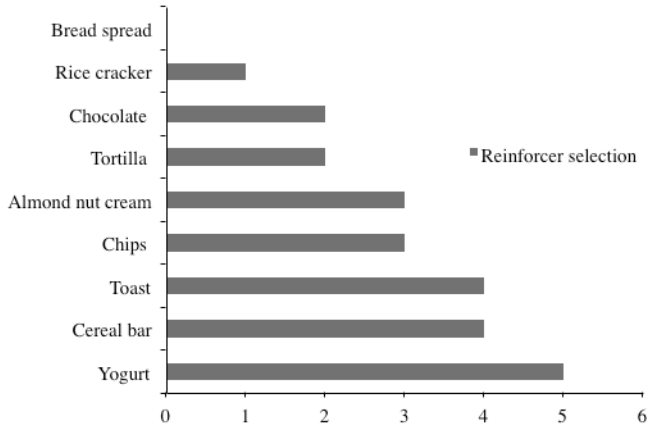

Figure 4. Results from reinforce selection gathered for all participants in the Mand group.

was the bottom ranked item during the reinforcer selection.

DISCUSSION

According to the results, only three of nine participants in the tact group and one in the mand group met criterion for stimulus equivalence class formation. Thus, in this study, the pre-training of abstract stimuli to exert control over tact and mand responses was related to a poor performance in equivalence class formation, a finding that is contrary to previous studies that showed an enhancement effect from acquired meaningfulness (e.g., Arntzen, 2004; Arntzen & Lian, 2010; Arntzen & Mensah, 2020).

First, Almeida, and De Rose (2015) argue that the pre-training of a previously meaningless stimulus strengthens stimulus dimensions (e.g., valence) that account for equivalence class enhancement. Therefore: (1) the strengthened stimulus dimensions would be part of the variables responsible for stimulus meaningfulness and (2) the role of pre-training would be to strengthen a particular or some stimulus dimensions.

In this case, one way to explain the contradictory results of the present experiment is to argue that pre-training abstract stimuli to exert control over tact and mand responses does not strengthen stimulus dimensions that account for equivalence class enhancement, whereas other types of pre-training arrangements do so (Fields & Arntzen, 2018). In fact, Almeida, and de Rose (2015) discussed their results in terms of strengthening of stimulus valence rather than stimulus meaningfulness.

Second, some observed effects of meaningful stimuli may be a puzzle. For instance, in some studies (e.g., Arntzen *et alia*, 2014; Doran & Fields, 2012; Fields *et alia*, 2012; Nartey, Fields, & Arntzen, 2014) abstract stimuli with an acquired history of meaningfulness produced lower stimulus-equivalence performance outcomes than did the use of familiar pictures. Moreover, in the present study, the pre-training of abstract stimuli to exert control over verbal operants did not suffice to produce equivalence class enhancement. Considering the variability of these outcomes, further research is needed to clarify the sources of stimulus control attributed to stimuli with an acquired history of meaningfulness.

Third, another reason for the contradictory results of the present experiment might be due to a possible failure in the transfer of stimulus control from one condition to another. For instance, in their study investigating identity conditional discrimination and stimulus equivalence class enhancement, Arntzen *et alia* (2014) reported that no participants demonstrated stimulus equivalence performances after pre-training of identity conditional discrimination under 0s delay. The authors reasoned that a potential blocking effect was the specific features of identity versus arbitrary matching-to-sample. That is, during the identity matching condition, the participants were asked to relate stimuli that shared the same physical properties, whereas during the arbitrary matching condition, they were rather asked to relate stimuli that did not have any physical features in common. Thus, the different sources of stimulus control for responding might have deteriorated relational performances overall. In the case of the present experiment, it is possible that the stimulus control acquired over tact and mand responses did not transfer to the conditional discrimination training during baseline.

Noteworthy is the fact that the majority of the participants in both groups had previous experience with participating in the study by Arntzen, Eilertsen, and Fagerstrøm (2016) and this did not seem to have a boosting effect in producing stimulus equivalence class enhancement. As measured by the card sorting procedure, none of the participants grouped stimuli according to the experimenter-defined classes prior to training, confirming that the card sorting procedure is an effective measure of the participants' previous experience (Arntzen, Norborn, & Fields, 2015).

According to the data, there were no differences between groups in terms of number of serialized and mixed blocks required to meet criterion during baseline acquisition. These results are again inconsistent with some studies (Arntzen, Granmo, & Fields, 2016) in which the participants who passed tests for stimulus equivalence class formation acquired baseline relations after a lower number of training trials when compared to those who did not pass.

One possible explanation for that is the fact that only three participants in the tact group and only one participant in the mand group demonstrated stimulus equivalence class formation. We argue that the small number of participants brings individual differences to play a major role in this case. Perhaps a larger number of participants passing tests for stimulus equivalence in each group would produce different results than those observed in the present experiment.

A data set that deserves further explanation is the average number of serialized blocks in the mand group not meeting criterion, which settled at 17.3. This group had an outlier participant (P11) who required many more training blocks than the other participants (36 blocks against a maximum of 20 blocks needed for the other participants). On a volunteer basis, this particular participant reported a high level of frustration about receiving negative programmed consequence ("wrong"). Frustration during the learning process has been reported in other studies (Oliveira *et alia*, 2016). Because this may interfere with learning, as it seems to be the case in our study, further research is necessary to clarify the effects of frustration on participant performance.

According to results of the card sorting tests for the participants in the tact and in the mand groups who met criterion for stimulus equivalence class formation, only one participant in the mand group showed grouping consistent with the experimenter-defined classes during the post-class formation, whereas none of the participants in the tact group did so. For the participants not meeting criterion, four in the tact and four in the mand group showed partial formation of stimulus equivalence classes, that is, formed incomplete stimulus equivalence classes.

Although previous studies (Arntzen, Granmo, & Fields, 2016) have found a consistency between categorization performances during the post-class-formation card sorting and the tests for stimulus equivalence, results from the present study are inconclusive about this relationship. However, we observed that most of participants who did not demonstrate stimulus equivalence class formation formed partial classes, a finding also reported in the study by Fields *et alia* (2012).

Although a systematic preference assessment and reinforcer evaluation were not carried out, data from the mand pre-training suggest that the items that the participants chose during reinforcer evaluation functioned as reinforcers, since the participants achieved 100% correct responses after 2,5 sessions on average, which was obtained by dividing the values referring to the number of sessions to criterion for each participant by the total number of values. We also ensured that the target establishing operation for mand responses (making requests) was in effect by withholding access to desired items. Supporting this, some authors argue that contriving establishing operations may be one of the best alternatives to teach mands in controlled environments (Oleson & Baker, 2014; Sundberg & Michael, 2001).

Data from the tact pre-training condition also showed fast response acquisition as participants achieved 100% correct responses in 2,2 sessions on average. In the present study, we adopted non-sense three-letter words (Lowe, Horne, & Hughes, 2005; Tyndall, Roche, & James, 2004) as labels for each abstract stimulus used in the tact pre-training; however, because university students have a highly elaborate verbal repertoire, we do not know whether using more complex words with other features (e.g., length, pronounceability) would produce different results in terms of tact repertoire acquisition and equivalence class enhancement.

Some limitations encountered in this study and suggestions for future research are discussed next. First, we used a small number of participants making it difficult to provide a comprehensive approach of the strength of the findings. Second, preference assessment procedures, which are needed to ensure the presence of a motivating operation (Sundberg *et alia*, 2002), were not carried out in this study; thus, we suggest future studies covering this gap. Finally, we did not adopt instruments to measure acquired meaningfulness of abstract stimuli (Almeida & de Rose, 2015), which could explain the absence of stimulus control transfer between conditions. It may be the case that stimulus control over tact and mand responses are not sufficient to infer stimulus meaningfulness.

The present study reinsured the need for further research on the variables accounting for stimulus equivalence class enhancement. A behavioral definition of stimulus meaningfulness might be still a challenge to be pursued through data-oriented refinements. Summarizing, the learning of symbols occurs in a continuum and involves several behaviors that differ in many ways, which gives to any disciplines in this field near-to-infinite possibilities of scientific discovery.

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