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ORIGINAL ARTICLE

The Role of Meaningful Stimuli in Large Stimulus Classes

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Abstract

The present experiment examined the effect of having the D-stimuli as meaningful pictures when establishing 18 conditional discriminations and testing for the emergence of three 7-member equivalence classes (A→B→C→D→E→F→G). Twenty participants were randomly assigned to two main experimental groups. In one group, the participants were exposed to training and testing with abstract stimuli only (the ABS group). In the other group, the participants were exposed to D-stimuli as meaningful pictures and the A, B, C, E, F, and G stimuli as abstract stimuli (the PIC group). If the participants in the PIC group did not form equivalence classes, they repeated the experiment in a new condition (DA-as-PIC) that had a new stimulus set different from the PIC group where the D and A stimuli are meaningful stimuli whereas the B, C, E, F, and G stimuli were abstract stimuli. The participants who did not form equivalence classes in the DA-as-PIC condition repeated the experiment in a new condition (DAG-as-PIC) that had a new stimulus set different from the PIC and DA-as-PIC where the D, A, and G stimuli are meaningful stimuli whereas the B, C, E, and F stimuli were abstract. The main findings from the experiment showed that 1 of 10 participants in the ABS group formed equivalence classes, whereas 5 of 10 participants in the PIC group formed equivalence classes. Furthermore, the result showed that three of the five participants who did not form equivalence classes in the PIC group formed classes in the DA-as-PIC condition. Finally, two of the five participants who did not form equivalence classes in the DA-as-PIC condition formed classes in the DAG-as-PIC condition.

Keywords abstract stimuli · meaningful stimuli · sorting · stimulus equivalence

Stimulus equivalence refers to stimulus relations that are untaught but emerge after a set of new relations have been learned in conditional-discrimination training. The stimulus relations qualify as stimulus equivalence if they have the properties of reflexivity, symmetry, and transitivity. The property of reflexivity occurs if a participant without explicit training can match a stimulus onto itself in a select relation task. Furthermore, a positive outcome on a symmetry test occurs if an individual is able to match the stimulus B to the stimulus A after having been taught to match A to B in a conditional-discrimination training. Transitivity occurs when an individual after having been taught to match A to B, and B to C, can match A to C without training (e.g., Sidman & Tailby, 1982).

Three training structures have been used to establish necessary prerequisites to test for emergent relations: linear series (LS), many-to-one (MTO), and one-to-many (OTM; e.g., Saunders et al., 1993). The LS training structure is such that conditional relations are taught from one stimulus to a comparison stimulus, after which the comparison stimulus then serves as sample stimulus to be related to a new comparison stimulus and so on. Thus, depending on the number of stimuli in the set, stimuli can serve as sample and comparison stimuli (i.e., A→B, B→C, C→D). The MTO training structure, also known as comparison-as-node, involves training many sample stimuli to one comparison stimuli (i.e., A→D, B→D, and C→D). With the OTM also referred to as sample-as-node, conditional relations are taught such that one sample stimulus is related to other comparison stimuli (i.e., A→B, A→C, and A→D; e.g., Arntzen & Hansen, 2011; Saunders & Green, 1999).

The use of different training structures has been shown to have different effects on equivalence class formation (see Arntzen, 2012). The LS has been found to produce lower equivalence class formation outcomes because, unlike the OTM and MTO, sample stimuli in LS fluctuates in comparison to previous trials (e.g., Arntzen, 2012; Arntzen & Holth, 1997, 2000;

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Saunders et al., 2005), therefore, it has been used mostly to examine the variables that influence class formation yields (e.g., Arntzen & Mensah, 2020, Arntzen & Nartey, 2018; Arntzen et al., 2018a; Mensah & Arntzen, 2017; Fields et al., 2012). The present experiment, therefore, employs the LS to investigate the effects of type of stimuli on equivalence class formation.

An equivalence class is made of a specified number of stimuli that are perceptually different from each other but become related to each other through conditional-discrimination training (Fields & Verhave, 1987; Sidman & Tailby, 1982). Several experiments have found that an equivalence class formation is enhanced when meaningful stimuli are used in a set of abstract stimuli relative to only abstract stimuli (e.g., Arntzen, 2004; Arntzen & Lian, 2010; Bentall et al., 1993; Holth & Arntzen, 1998). An abstract stimulus is a stimulus lacking any specific discriminative function (Arntzen et al., 2018b). The types of abstract stimuli that have been used in previous research have included Greek letters, stimuli that are presumed unfamiliar to participant (Sidman & Tailby, 1982), syllables with no meaning in language, symbols from alphabets that the participant has no knowledge of, and unnamable or difficult to name (Nedelcu et al., 2015). A meaningful stimulus, also referred to as a familiar picture or nameable stimulus, is any stimulus that has meaning, can evoke language allowing it to be named efficiently, and has several verbal functions serving as tacts and intraverbals. Thus, meaningful stimuli include nameable pictures, identifiable smell, or familiar words spoken.

A series of experiments have examined equivalence class formation as a function of the inclusion of meaningful stimuli in a set of abstract stimuli in a three 5-member linear series training structure (A→B→C→D→E). In general, the finding in this line of research is that when all stimuli are abstract shapes (the ABS group) a small number of participants form equivalence classes. In contrast, when meaningful pictures are C stimuli and the rest of the stimuli are abstract shapes (the PIC group) the number of participants who respond in accordance with stimulus equivalence is increased substantially (e.g., Arntzen & Mensah, 2020; Arntzen & Nartey, 2018; Arntzen et al., 2014, 2015a; Arntzen et al., 2018a, 2018b; Fields et al., 2012; Mensah & Arntzen, 2017; Nartey et al., 2014, 2015a, 2015b; Nedelcu et al., 2015). For example, in Fields et al. (2012), the results showed that when all the stimuli were abstract, none of 10 adult participants responded in accordance with stimulus equivalence. When the A, B, D, and E stimuli were abstract shapes, and the C stimuli were meaningful pictures, 8 of 10 participants responded in accordance with equivalence.

The nodal structure (the number of nodes and singles) of an equivalence class has been found to be a determinant of equivalence class formation (Fields & Verhave, 1987). An equivalence class, for example, represented by A→B→C→D→E contains three nodal stimuli (B, C, and D) and two singles (A and E). Fields et al. (1997) in an experiment trained necessary conditional discriminations in college students and tested if one-node three-, five-, or seven-member classes or three-node five- or seven-member classes emerged. Fields et al. (1997) found that the number of participants who formed classes was a direct function of the number of nodes in a class. Arntzen and Holth (2000) also found that participants are more likely to form classes when a fewer number of members exist in a class relative to when a larger number of members exist in a class.

Sorting has also been used as a common measure of categorization or concept formation (Arntzen et al., 2017; Arntzen, Norbom et al., 2015; Fields et al., 2014; Fields et al., 2012) but the use of this technique in stimulus equivalence research is still emerging. Findings in respect with sorting measures in equivalence class formation so far have shown a consistent performance in equivalence class formation after conditional discrimination training, and categorization or sorting. The aforementioned studies have shown that participants who showed the formation of equivalence class formation in the MTS-based test for emergent relations, showed the class formation in a postsorting class formation test. Based on these findings, this experiment also seeks to find out whether sorting still provides an alternative measure of equivalence class formation.

At present, the experiments on the effect of meaningful stimuli on class formation have used fewer members (mostly five members with three nodes; e.g., Arntzen & Nartey, 2018; Arntzen, Nartey et al., 2015; Arntzen et al., 2018a, 2018c; Fields et al., 2012; Mensah & Arntzen, 2017). These experiments have found that the inclusion of meaningful stimuli as the middle node in a set of abstract stimuli enhances class formation yields within the range of 70%–80%. Despite this finding, relatively little is known about class formation yields as a function of the inclusion of meaningful stimuli in larger classes. Sorting has also been used as a common measure of categorization or concept formation (Arntzen et al., 2017; Arntzen, Norbom et al., 2015; Fields et al., 2014; Fields et al., 2012) but the use of this technique in stimulus equivalence research is still emerging and inconclusive. Whereas findings from Mensah and Arntzen (2017) and Fields et al. (2012) show that participants who form equivalence classes in an MTS-based test for emergent relations also formed classes in a sorting test after MTS-based training and testing for emergent relations, findings from Arntzen et al. (2021) and Arntzen et al. (2017) show a discordance between performance on the MTS-based test for emergent relations and performance on the sorting test after MTS-based training and testing for emergent relations. The present experiment therefore extends the existing literature on meaningful stimuli as a function of equivalence class formation in larger classes. Thus, this study investigated (1) the extent to which equivalence class formation as a function of meaningful stimuli is modulated by larger to-be formed classes with higher number of nodes, (2) the extent to which increasing the number of meaningful stimuli in a set of abstract stimuli enhances equivalence class formation by using single-subject manipulations, and (3) the concordance between MTS performance on emergent relations tests and sorting tests.

Method

Participants

Twenty university students (12 females and 8 males) voluntarily participated in this experiment. The participants were aged 17 to 27 years ($M = 21.4$, $SD = 2.23$). When participants arrived for the experimental session, they were given an informed consent form. The participants were asked to read the informed consent form and consent to participate in the experiment. The form included general information about the experimental situation and the duration of the experiment (about 100 min). Participants were also informed that they could quit at any time without any negative consequences. All participants were fully debriefed after they had finished the experimental session and paid 50 Ghana Cedis (an equivalent of US$11) for participating in the experiment.

Apparatus and Setting

The venue for this experiment was one of the lab rooms at the University of Ghana, Legon. The lab room was approximately 7 m square and furnished with tables and chairs. This experiment used HP Compaq nc6320 computer laptop running Windows 7. The computer had a 43.18 cm screen. A computer mouse was used to click on the stimuli displayed on the screen. Conditional-discrimination training and testing sessions were all conducted with a customized matching-to-sample (MTS) software program. This software program controlled the presentation of stimuli and recorded the responses in the form of the number of training trials, the first trial number, correct or incorrect response choices, and the programmed consequences. In addition, the software program recorded a summary of all training and testing trials; baseline, symmetry, one-node, two-node, three-node, four-node, and five-node trials.

Stimuli

Abstract and meaningful pictorial stimuli were used in the conditional-discrimination training and testing. A sample of the stimulus sets used in this experiment are displayed in Figure 1 and were selected from a plethora of abstract and meaningful stimuli that have been used in previous experiments (e.g., Arntzen & Mensah, 2020). The abstract stimuli used in the present experiment included symbols from alphabets that participants were unlikely to know or be able to name. All stimuli used in this experiment were randomly selected and displayed on a white background on the screen of the computer. The size of each stimulus displayed on the screen of the computer was 9.4 cm x 3.4 cm.

Design

The experiment used a combination of between-group and within-group experimental design. Ten participants each were assigned to the ABS and PIC groups. Five participants who failed to form classes in PIC repeated the experiment in DA-as-PIC, and two participants who failed to form classes in DA-as-PIC repeated the experiment in DAG-as-PIC. The between-group experimental design was used to examine the difference in performances for the two main experimental groups: the ABS Group and the PIC Group. The within-group design was used to examine whether the inclusion of more pictures to replace abstract stimuli will facilitate equivalence class formation for participants who failed to form classes after conditional-discrimination training and testing in the PIC group. The participants in the PIC group who failed to form classes were exposed to a new experimental condition (DA-as-PIC) that had a new set of stimuli where the D and A stimuli were meaningful stimuli, with the B, C, E, F, and G stimuli being abstract stimuli. The participants who failed to respond in accordance with stimulus equivalence in the DA-as-PIC condition were exposed to a new experimental condition (DAG-as-PIC) that had a new set of stimuli where the D, A, and G stimuli were meaningful stimuli, with the B, C, E, and F stimuli being abstract stimuli.

Procedure

Preexperimental Sorting Test

Participants who agreed to participate in the experiment were given 21 plastic-laminated cards that corresponded to each of the "to-be-displayed stimuli or image" in the conditional-discrimination training of the group to which they were assigned (preexperimental sorting). On receiving the laminated cards, participants were instructed to "put the cards into groups." Participants' performance on this task were recorded by the experimenter. The preexperimental class formation sorting test served as a means of ensuring that participants did not have any class formation experience before the experiment.

Fig. 1 An Example of the Stimulus Set Used as Members of the To-Be-Formed Equivalence Classes

Note. The stimuli used as members of the to-be-formed equivalence classes. The top section shows the 21 abstract stimuli used in the ABS Group, whereas, the bottom section shows the meaningful stimuli that replaced only the D abstract stimuli in PIC Group.

Instruction

Once preexperimental sorting was completed, participants were instructed to click on the computer screen using the computer mouse. The computer screen displayed the following instructions:

> 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!

No further instructions were given before and after the experiment started. Participants were not informed on how fast or slow the selection clicks throughout the experimental session should be.

Trial Structure and Contingencies

Regardless of the experimental group or condition, participants were trained 18 conditional discriminations arranged in a linear series structure using the simultaneous protocol after the formation of three 7-member equivalence classes were tested. Fields et al. (1997) note that the simultaneous protocol involves presentation of all training trials in a randomized order in training blocks followed by a test block including all possible emergent relations in a randomized order. Training trials started with the presentation of a sample stimulus in the middle of the screen of a computer. Participants responded to the stimulus by clicking on the stimulus with a computer mouse. The click on the stimulus is followed by the display of three comparison stimuli presented at three of the four corners of the computer screen along with the sample stimulus still at the center of the computer screen. Throughout the experiment, the location of the comparison stimuli was random. A click on one of the comparison stimuli was followed by the presentation of words such as *correct, very good, super,* or *excellent* on the screen of the computer if the selected comparison stimulus was correct. However, if the selected comparison stimulus was incorrect, the word *wrong* was presented on the screen of the computer. Programmed consequences presented after the selection of the comparison stimulus in the training trials were displayed at the center of the computer screen for 1,000 ms. An intertrial interval of 500 ms followed the termination of program consequences. The mouse cursor was always reset to the center of the computer screen between trials.

Acquisition of Baseline Relations (Phases 1–11)

Acquisition of baseline relations in the present experiment for all the experimental groups and conditions was trained in 11 phases with a presentation of programmed consequences after the selection of a comparison in each trial (see Table 1 for an overview of each of the experimental phases). A mastery criterion of 90% correct responding was required in each phase in order to progress to the next phase. Phase 1 of the baseline relation training was for the training of AB relations in a block containing nine trials with three trials of each relation (A1B1, A2B2, and A3B3). The participant had to respond correctly on all the nine trials to achieve the mastery criterion. Baseline training relations requirements in Phase 2 were the same as Phase 1 except that this phase trained BC relations (B1C1, B2C2, and B3C3). Phase 3 consisted of an 18-trial block with mixing of AB and BC relations. The fourth phase was the same as the first phase except that this phase trained CD relations (C1D1, C2D2, and C3D3). Phase 5 consisted of a 36-trial block with mixing of AB, BC, and CD relations. Phase 6 of baseline relations training was the same as Phase 1 except that this phase trained DE relations (D1E1, D2E2, and D3E3). Phase 7 consisted of a 45-trial block with mixing of AB, BC, CD, and DE relations. Phase 8 of baseline relations training trials was the same as Phase 1 except that this phase trained EF relations (E1F1, E2F2, and E3F3). Phase 9 consisted of a 54-trial block with mixing of AB, BC, CD, DE, and EF relations. Phase 10 of baseline training was the same as Phase 1 except that this phase trained FG relations (F1G1, F2G2, and F3G3). Phase 11 consisted of a 63-trial block with mixing of all the trained relations in the first 10 phases (AB, BC, CD, DE, EF, and FG). This last phase was followed by a block with trials to ensure that all baseline relations trials were presented in an equal number of times.

Maintenance of baseline trials Training blocks for participants continued after the acquisition of the baseline with a reduction in the probability of programmed consequences (Phases 12–15 in Table 1). The percentage of programmed consequences trials in training blocks after the acquisition phases were systematically reduced to 75%, 50%, 25%, and then 0%. The mastery criterion was 90 % correct choices in a block of 54 training trials.

Emergent relations test block Once a participant responded to the criterion in the last baseline maintenance phase, a test block for emergent relations was administered. The test block consisted of 378 trials made up of 54 baseline trials, 54 symmetry trials, 90 one-node trials, 72 two-node trials, 54 three-node trials, 36 four-node trials, and 18 five-node trials. All the 378 trials in this block were presented randomly and without programmed consequences (see Table 1). Furthermore, each test relation in the test block was presented three times (see Table 1). For a participant to respond in accordance with stimulus equivalence, the participant had to select at least 90% correct choices for each type of the test trials (i.e., symmetry, one-node, two-node, three-node, four-node, and five-node).

Postexperimental Sorting Test

Upon completion of the MTS-based test for emergent relations, participants were again given the 21 plastic-laminated cards that corresponded to each of the "displayed stimuli or image" in their designated conditional-discrimination training and testing experimental condition or the group to which they were assigned to. On receiving the laminated cards, participants were instructed to "put the cards into groups." Participants' performance on this task were recorded by the experimenter. The performance of participants on this task were also recorded. This postexperimental sorting test served as an additional measure of stimulus class formation following the MTS-based training and testing.

Results

Preexperimental Sorting

ABS and PIC Groups

No participant sorted the cards in accordance with the experimenter-defined classes prior to the conditional-

Table 1 Sequence of Training and Testing

Experimental Phases	Trial Types	% Program Consequences	Number of Trials
	Acquisition of baseline relations (All trial types presented randomly)		
1. Serialized trials	A1B1, A2B2, A3B3	100	9
2. Serialized trials	B1C1, B2C2, B3C3	100	9
3. Serialized trials	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3	100	18
4. Serialized trials	C1D1, C2D2, C3D3	100	9
5. Serialized trials	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3	100	36
6. Serialized trials	D1E1, D2E2, D3E3	100	9
7. Serialized trials	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3, C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	100	45
8. Serialized trials	E1F1, E2F2, E3F3	100	9
9. Serialized trials	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3, C1D1, C2D2, C3D3, D1E1, D2E2, D3E3, E1F1, E2F2, E3F3	100	54
10. Serialized trials	F1G1, F2G2, F3G3	100	9
11. Serialized trials	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3, C1D1, C2D2, C3D3, D1E1, D2E2, D3E3 E1F1, E2F2, E3F3, F1G1, F2G2, F3G3	100	63
12. Mixed trials (trials presented randomly)	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3, C1D1, C2D2, C3D3, D1E1, D2E2, D3E3, E1F1, E2F2, E3F3, F1G1, F2G2, F3G3	75	54
13. Mixed trials (trials presented randomly)	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3, C1D1, C2D2, C3D3, D1E1, D2E2, D3E3, E1F1, E2F2, E3F3, F1G1, F2G2, F3G3	50	54
14. Mixed trials (trials presented randomly)	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3, C1D1, C2D2, C3D3, D1E1, D2E2, D3E3, E1F1, E2F2, E3F3, F1G1, F2G2, F3G3	25	54
15. Mixed trials (trials presented randomly)	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3, C1D1, C2D2, C3D3, D1E1, D2E2, D3E3, E1F1, E2F2, E3F3, F1G1, F2G2, F3G3	0	54
Test for emerged relations (trials presented randomly intermixed)			
Baseline trials	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3, C1D1, C2D2, C3D3, D1E1, D2E2, D3E3, E1F1, E2F2, E3F3, F1G1, F2G2, F3G3	0	54
Symmetry trials	B1A1, B2A2, B3A3, C1B1, C2B2, C3B3, D1C1, D2C2, D3C3E1D1, E2D2, E3D3, F1E1, F2E2, F3E3, G1F1, G2F2, G3F3	0	54
1 Node Trials	A1C1, A2C2, A3C3, B1D1, B2D2, B3D3, C1E1, C2E2, C3E3, D1F1, D2F2, D3F3, E1G1, E2G2, E3G3, C1A1, C2A2, C3A3, D1B1, D2B2, D3B3, E1C1, E2C2, E3C3, F1D1, F2D2, F3D3, G1E1, G2E2, G3E3	0	90
2 Node Trials	A1D1, A2D2, A3D3, B1E1, B2E2, B3E3, C1F1, C2F2, C3F3, D1G1, D2G2, D3G3, D1A1, D2A2, D3A3, E1B1, E2B2, E3B3, F1C1, F2C2, F3C3, G1D1, G2D2, G3D3	0	72
3 Node Trials	A1E1, A2E2, A3E3, B1F1, B2F2, B3F3, C1G1, C2G2, C3G3, E1A1, E2A2, E3A3, F1B1, F2B2, F3B3, G1C1, G2C2, G3C3	0	54
4 Node Trials	A1F1, A2F2, A3F3, B1G1, B2G2, B3G3, F1A1, F2A2, F3A3, G1B1, G2B2, G3B3	0	36
5 Node Trials	A1G1, A2G2, A3G3, G1A1, G2A2, G3A3	0	18

Note. For all the training phases, there are three trials of each relations of the three classes except for phases 5, 7, 9, and 11, which have nine more additional trials.

discrimination training and testing regardless of the experimental group (see Figure 2).

D-as-PIC and DAG-as-PIC Conditions

Regardless of experimental conditions, none of the participants sorted the cards in the preexperimental sorting test in accordance with the experimenter-defined classes.

Acquisition of Baseline Relations

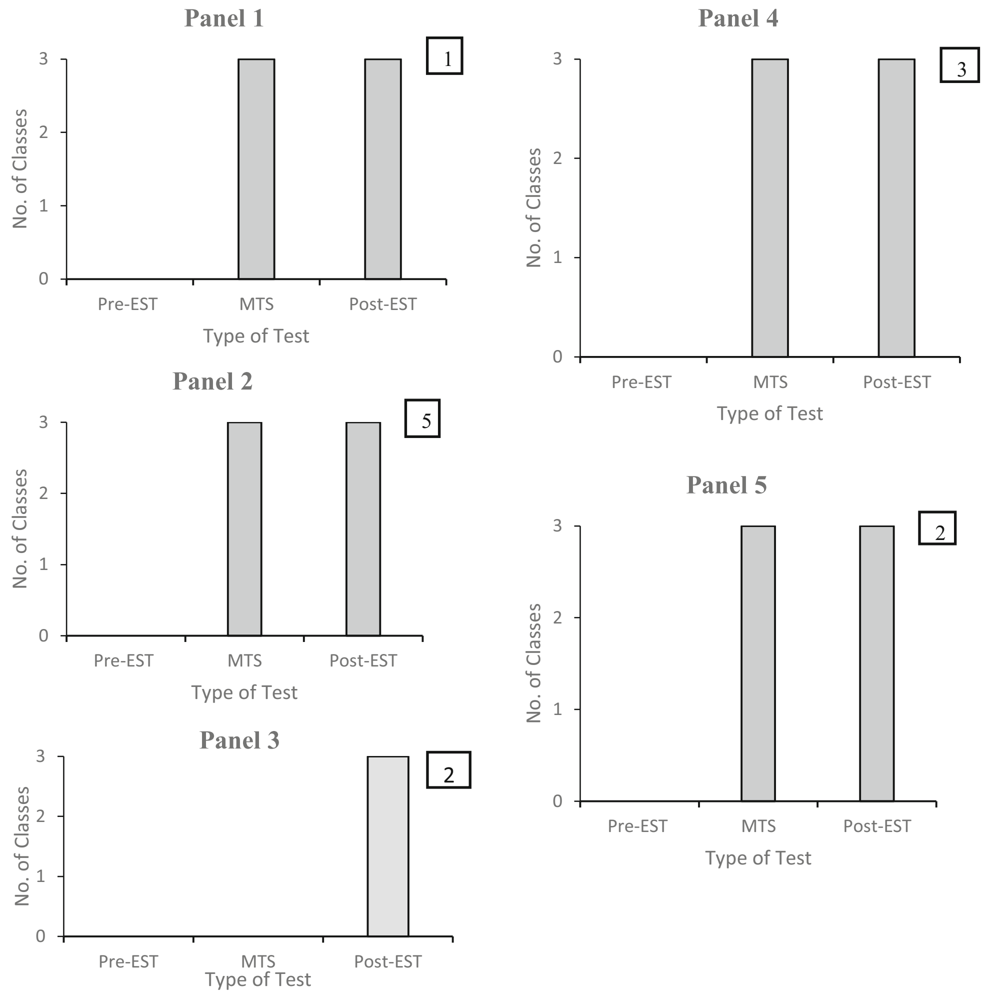
ABS and PIC Groups

A visual inspection of Figure 3 shows that participants required an average number of trials of 913.5 and 786.2 to acquire baseline for the ABS and PIC groups, respectively. However, a *t*-test showed no significant difference in the number of trials required to acquire baseline between the ABS and the PIC groups, $t(1, 18) = 1.3$, $p = .21$. The six participants who formed classes regardless of the experimental group required a mean of 784.5 trials to acquire the baseline relations relative to 877.86 mean trials for the 14 participants who did not form classes. A *t*-test showed no significant difference in the number of trials needed for baseline acquisition between participants who formed classes and participants who did not form classes, $t(1, 18) = -.85$, $p = .41$.

DA-as-PIC and DAG-as-PIC Conditions

Participants in the DA-as-PIC and the DAG-as-PIC conditions required an average of 603 and 666 trials, respectively, to acquire baseline relations (see Figure 4).

Fig. 2 Preexperimental Sorting, Equivalence Class Formation, and Postexperimental Sorting Tests Outcomes for Participants



Note. The test types are listed from left to right in their order of administration. The number of participants showing each pattern across test types is indicated in the box to the right of each panel. Pre-EST = pre-experimental sorting test, MTS = matching-to-sample test for emergent relations, Post-EST = post-experimental sorting test.

Equivalence Class Formation

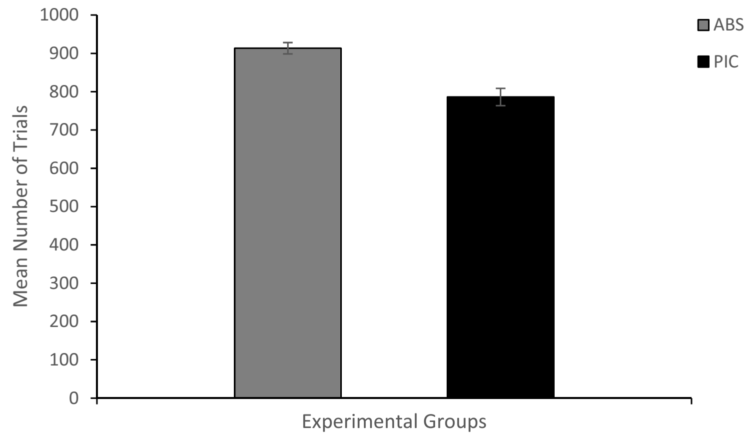
ABS and PIC Groups

As shown in Panel 1 of Figure 2, 1 of 10 participants in the ABS group responded in accordance with equivalence class formation, whereas 5 of 10 participants (see Panel 2 of Figure 2) in the PIC group formed equivalence classes. A Fisher's Exact Test showed that class formation yields for PIC relative to ABS was nonsignificant, $p = .07$, 95% CI [.002, 1.56].

DA-as-PIC and DAG-as-PIC Conditions

Panels 4 and 5 of Figure 2 show class formation performance for the DA-as-PIC and DAG-as-PIC conditions. Three of the five participants who did not form classes in the PIC group formed equivalence classes in the DA-as-PIC condition (see Panel 4). Furthermore, all the participants in the DAG-as-PIC condition formed equivalence classes (see Panel 5).

Fig. 3 Mean Number of Trials Needed to Acquire Baseline Relations in the Experimental Groups (ABS and PIC). *Note.* ABS = All stimuli are abstract, PIC = D stimuli are meaningful pictures in the stimulus set and the rest abstract



Note. ABS = All stimuli are abstract, PIC = D stimuli are meaningful pictures in the stimulus set and the rest abstract.

Postexperimental Sorting

ABS and PIC Groups

The one participant who formed equivalence classes in ABS also sorted the stimuli in accordance with the experimenter-defined classes in the postexperimental sorting test (see Panel 1 of Figure 2). Furthermore, the five participants who formed equivalence classes in PIC also sorted the stimuli in accordance with the experimenter-defined classes in the postexperimental sorting test (see Panel 2 of Figure 2). Two participants in PIC who failed to sort the stimuli in accordance with the experimenter-defined classes and also failed the MTS-based test for emergent relations, sorted the stimuli in accordance with the experimenter-defined classes in the postexperimental sorting test (see Panel 3 of Figure 2).

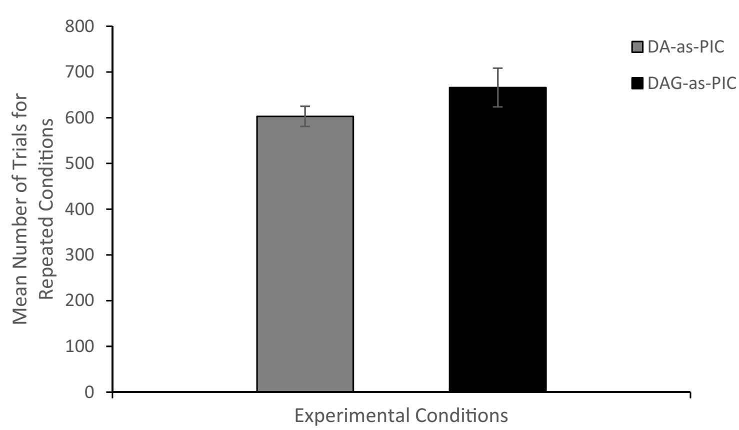
D-as-PIC and DAG-as-PIC Conditions

The three participants who formed equivalence classes in DA-as-PIC also sorted the stimuli in accordance with the experimenter-defined classes in the postexperimental sorting test (see Panel 4 of Figure 2). Furthermore, the two participants in DAG-as-PIC also sorted the stimuli in accordance with the experimenter-defined classes in the postexperimental sorting test (see Panel 5 of Figure 2).

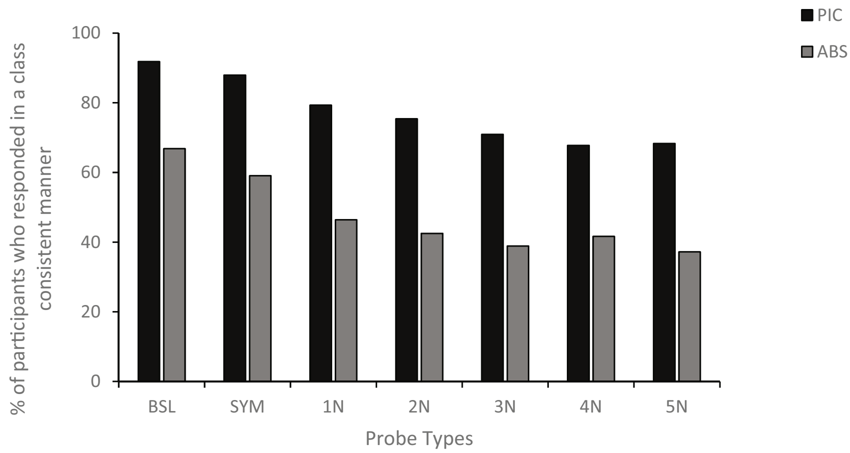
Number of Nodes

Figures 5 and 6 show class formation yields in relation to the number of nodes across the test relations. The results show that except for the DAG-as-PIC condition (see Figure 6), the performance of participants was an inverse function of the number of nodes. Thus, participants responded more correctly on fewer number of

Fig. 4 Mean Number of Trials Needed to Acquire Baseline Relations in the Repeated Experimental Conditions (DA-as-PIC and DAG-as-PIC). *Note.* DA-as-PIC = D and A stimuli are pictures in the stimulus set, DAG-as-PIC = D, A, and G stimuli are meaningful pictures in the stimulus set



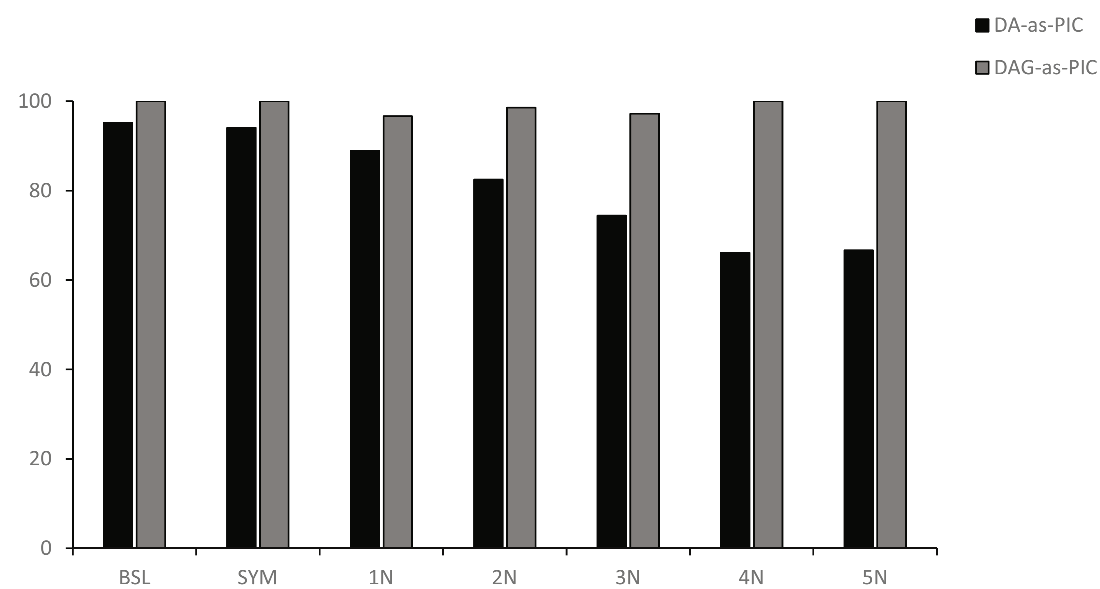
Note. DA-as-PIC = D and A stimuli are pictures in the stimulus set, DAG-as-PIC = D, A, and G stimuli are meaningful pictures in the stimulus set.



Note. ABS = All stimuli are abstract, PIC = D stimuli are meaningful pictures in the stimulus set whereas A, B, C, E, F, and G stimuli are abstract, BSL = baseline, SYM = Symmetry, 1N = one-node, 2N = two-node, 3N = three-node, 4N = four-node, 5N = five-node.

Fig. 5 Class-Consistent Responses of Participants in Relation to Number of Nodes

nodes and more incorrectly as the number of nodes increased. Furthermore, a *t*-test showed significant and better performances for the PIC group relative to the ABS group across the different number of nodes: one-node, $t(1,18) = 3.3$, p =.00, two-node, $t(1,18) = 3.0$, p =.01, three-node, $t(1,18) = 2.62$, p =.02, four-node, $t(1,18) = 1.96$, p = 04, and five-node, $t(1,18) = 2.23$, p = 04. This finding suggests that the inclusion of meaningful pictures in a set of abstract stimuli decrease the effect of the number of nodes on test outcomes.



Note. DA-as-PIC = D and A stimuli are meaningful pictures in the stimulus set and the rest of the stimuli are abstract, DAG-as-PIC = D, A, and G stimuli are pictures in the stimulus set and the rest of the stimuli are abstract, BSL = baseline, SYM = Symmetry, 1N = one-node, 2N = two-node, 3N = three-node, 4N = four-node, 5N = five-node.

Fig. 6 Class-Consistent Responses of Participants in Relation to Number of Nodes

Different Types of Response Patterns

Three response patterns occur in the response patterns of participants who failed to form classes in the MTS test for emergent relations. These response patterns are experimenter-defined classes, participant-defined classes, and indeterminate (see Mensah & Arntzen, 2017). A participant responds in accordance with experimenter-defined classes if test trials responses are consistent with experimenter-defined relations. Participant-defined classes response include participants selecting consistently same sample-comparison pairs every time during MTS-based testing that are inconsistent with experimenter-defined classes or sample-comparison pairs (e.g., selecting B2 instead of B1 in the presence A1 on all three test relations trials). Indeterminate responding occurs if a participant selects different and incorrect comparison stimulus for every sample stimulus in test relation trials.

The results from this analysis showed that 46.24% and 58.99% of probes trials produced responses in accordance with experimenter-defined classes for the ABS and the PIC groups, respectively. This result suggests that the inclusion of meaningful stimuli in the PIC group facilitated more correct test trial responses relative to the ABS group. Also, 8.38% and 15.08% of probes trials produced responses in accordance with participant-defined classes for the ABS and PIC groups, respectively. Lastly, 45.38% and 25.93% of probes trials produced indeterminate responses for the ABS and PIC groups, respectively. Furthermore, the results showed that 63.89%, 10.71%, and 25.4% of probe trials produced responses in accordance with experimenter-defined classes, participant-defined class, and indeterminate responses for the DA-as-PIC condition. These results suggest that responding in accordance with experimenter-defined classes, which consequently led to equivalence class formation, is influenced by the inclusion of meaningful stimuli in a set of abstract stimuli.

Discussion

The present experiment investigated the differential effects of meaningful stimuli on the formation of three 7-member classes. The findings of the experiment found that 1 of 10 participants and 5 of 10 participants formed classes in the ABS group and PIC group, respectively. Furthermore, the results showed that three of the five participants who did not form classes in the PIC group and participated in the DA-as-PIC condition formed classes. Two of the five participants who did not form classes in the DA-as-PIC condition and participated in the DAG-as-PIC condition formed classes.

Equivalence Class Formation Enhancement and Meaningful Stimuli

The findings from this experiment demonstrate that class formation yields are a function of the inclusion of a meaningful stimulus in a set of abstract stimuli. This finding is consistent and extends some earlier findings with smaller classes such as the three 5-member classes experiments (Arntzen & Nartey, 2018; Arntzen et al., 2014; Arntzen, Nartey et al., 2015; Arntzen et al., 2018a, 2018c; Mensah & Arntzen, 2017; Nedelcu et al., 2015).

Meaningful stimuli have been found to serve multiple behavioral functions as a result of their acquisition of stimulus control functions (discriminative and conditional) influences equivalence class formation (Fields et al., 2012; Nartey et al., 2014). Fields et al. (2012) and Travis et al. (2014) argue that the enhancement of class formation by a meaningful stimulus is most likely due to the meaningful stimuli being a member of an already established category or equivalence class before experimental training and testing. The authors suggest that the enhanced likelihood of equivalence class formation in a set of meaningless stimuli with one meaningful stimulus reflects the expansion of an already existing class of which the meaningful stimulus is a member. Thus, the meaningless stimuli come to be added to an already existing stimulus class containing the meaningful stimulus.

Despite the findings that the simultaneous protocol produces lower yields of class formation (e.g., Buffington et al., 1997, Arntzen et al., 2010; Arntzen & Hansen, 2011), the reduction in class formation yields from 50% for PIC to 10% for ABS cannot be attributed to the simultaneous matching-to-sample training procedure because participants in both PIC and ABS were exposed to the same training procedure. It is therefore plausible to conclude that the low-class formation yields in ABS is a function of the absence of at least a meaningful stimulus in the to-be-formed classes. Furthermore, it is also plausible to assume that the low yields in ABS may be a function of the functional disparity of the abstract stimuli leading to several overlapping responses that may have conflicted the experimentally defined classes (Sidman, 1994). Participants' performances in DA-as-PIC condition and the DAG-as-PIC condition can be attributed to reinforcement contingencies in the experiment, or experience resulting from repetition of training and testing procedures, or both. In terms of reinforcement contingencies, the present findings show that equivalence class formation is a function of the number or increasing number of meaningful stimuli in a set of abstract stimuli. This finding is consistent and replicates the findings of Arntzen and Mensah (2020) and Mensah and Arntzen (2017). As an alternative, the present findings can be attributed to order effects or retraining and retesting, and as such are consistent with findings from Buffington et al. (1997), Nartey et al. (2015a), and Wulfert et al. (1991).

Buffington et al. (1997) found in their study that pretraining of equivalence classes influenced the rate baseline acquisitions and equivalence class enhancement. Thus, retraining and retesting do enhance the emergence of relational control and consequently equivalence class formation. As stated earlier, this finding can also be a function of the combined effect of reinforcement contingencies and order effects. It is, therefore, imperative that future experiments control for order effects to ascertain the class-enhancing effect of increasing numbers of meaningful stimuli in three 7-member equivalence classes.

Stimulus Control Topography and Failed Class Formation Response Pattern

In general, test probes during emergent relations testing for participants who fail to form classes lead to responses in accordance with experimenter-defined classes, participant-defined classes or indeterminate responses. Responses that are in accordance with the experimenter-defined classes can be accounted for by the stimulus control procedure in the experiment, which produces controlling relations that are consistent with those intended by the experimenter whereas participant-defined classes, or indeterminate responses are as a result of the stimulus control procedure producing controlling relations that are not in accord with those intended by the experimenter (McIlvane & Dube, 1992). Furthermore, the results also showed that the extent of responding in accordance with experimenter-defined classes was a function of the inclusion of meaningful stimuli in to-be-formed classes. This finding is consistent with those reported by Mensah and Arntzen (2017) and Arntzen, Nartey et al. (2015a) and imply that the inclusion of pictures results in the stimulus control procedure producing controlling relations that are consistent with those intended by the experimenter. It is therefore plausible to suggest that stimulus control topographies coherence occasioning experimenter-defined classes responding is enhanced by the inclusion of familiar pictures in a set of abstract stimuli.

The present finding suggests that nonclass-indicative stimulus-control topographies can influence performances on failed equivalence class formation, baseline relations acquisition, and delayed equivalence class formation (Fields, Arntzen, & Doran, 2020). Juxtaposing these findings with a recent finding from Fields and Paone (2020), which showed that despite varied error percentages of baseline relations during concurrent training (highest), serial training (lower), and constructed response training (lowest), class formation yields was about the same across the three training conditions, there is a need for further studies to shift attention to yet unknown variables that occasion equivalence class formation during testing relative to training. It is important that future studies examine the predictive power of stimulus control topography coherence theory in equivalence class formation.

Nodal Structure and Emergent Relations

The class-formation yield of 50% in the present experiment (PIC group) is a drop relative to class formation outcomes of 70%–80% in experiments that have explored meaningful stimuli as a determinant of equivalence class formation in the emergence of three 5-member equivalence classes (e.g., Arntzen & Mensah, 2020; Fields et al., 2012; Mensah & Arntzen, 2017). Experiments that have trained conditional discriminations and tested for three 5-member equivalence classes using the LS training structure have had three nodes in their nodal structure, whereas the nodal structure of the present experiment consisted of five nodes. This finding is consistent with Arntzen and Holth's (2000) findings, which indicated that equivalence class formation probability was significantly reduced as a result of an increase in the class size. Fields et al. (1997) suggest that the number of nodes in an equivalence class is a determinant of class formation outcomes, with increasing numbers hindering class formation and vice versa. It is therefore plausible to suggest that the drop in class formation yield in the present experiment is a result of the increased number of nodes in the equivalence class, which decreases the positive effect of the inclusion of meaningful stimuli in equivalence class formation.

The present finding shows an inverse relationship between the number of nodes separating stimuli and participants' performances in terms of correct responding. This finding is consistent with the findings of Kennedy (1991), Buffington et al. (1997), Fields et al. (1997), Fields et al. (2012), and Arntzen and Holth (2000). In general, stimulus relations test performances have been found to be linked to the number of nodes that separates the stimuli (Fields et al., 1993). Therefore, class-consistent comparisons selection in derived relations probes is a function of number of nodes or nodal proximity (Fields et al., 1993). The present finding suggests that the relations among stimuli in different conditional discriminations are a result of the training cluster, which is a function of nodal proximity (Fields & Verhave, 1987) and develops separately from the formation of equivalence class (Fields et al., 1993).

Sorting

The present experiment replicates previous findings on the sorting tests and equivalence class formation (e.g., Arntzen, Granmo, & Fields, 2017; Arntzen, Norbom et al., 2015b; Fields et al., 2014; Fields et al., 2012; Mensah & Arntzen, 2017). The results show that all participants who responded in accordance with stimulus equivalence in the MTS-based emergent relations test, sorted the cards in accordance with the three experimenter-defined classes in the postclass formation sorting test for the ABS and PIC groups, as well as in the DA-as-PIC and the DAG-as-PIC conditions. These results suggest that although the postexperimental sorting stimulus classes are not stimulus equivalence classes, performance on the postexperimental sorting test after conditional-discrimination training can serve as a predictor for performance on the MTS-based test for emergent relations. Furthermore, two participants who did not respond in accordance with stimulus equivalence in the MTS-based emergent relations test in the PIC group sorted the cards in accordance with the three experimenter-defined classes in the postclass formation sorting test. This finding suggests that the MTS test may have provided a false negative result or sorting provided a false positive result, or the sorting test may have provided a more sensitive measure of class formation relative to the MTS test for emergent relations (Fields et al., 2014).

Limitations and Further Experiments

There are some limitations to the present experiment. First, the type of stimuli used may have accounted for the present results because the abstractness and meaningfulness of stimuli are still inconclusive. Thus, despite the preexperimental sorting to test for stimuli familiarity, it is plausible to assume that some of the abstract stimuli may have evoked naming during conditional-discrimination training and testing. It is imperative that future studies test for the abstractness and meaningfulness of stimuli before using them in equivalence class formation experiments. Future studies can also adopt the tailoring of stimuli technique (see Arntzen & Eilertsen, 2020), which uses preexperimental stimuli sorting classes of stimuli to be used in the conditional-discrimination training. Furthermore, the lack of control for experience or repeated training and testing in DA-as-PIC and DAG-as-PIC conditions limits the findings. It is plausible to suggest that class formation yields in the DA-as-PIC and the DAG-as-PIC conditions are not directly a result of the inclusion of additional pictures but rather the repetition of training and testing procedures, or both. In order to clarify these results, a future experiment should control for these effects by exposing participants who failed to form classes in the PIC group to extended cycles of training and testing without including more meaningful stimuli.

Another limitation is the lack of control for repeated training and testing for the ABS group. For example, a future experiment can examine whether additional cycles of training and testing with different stimulus sets of abstract shapes will increase the yields of equivalence class formation. In addition, a group experiment should be conducted in the future to allow for a comparative analysis of both results. Lastly, because the results show a negative effect of the number of nodes on the class-enhancing effect of a meaningful stimulus, it is suggested that future experiments adopt the MTO or OTM training structures because the number of nodes does not increase as a function of the number of members in the to-be-formed classes.

Conclusion

The present experiment examined the class-enhancing effect of meaningful stimuli in a set of abstract stimuli and found that the inclusion of a meaningful stimulus enhanced the formation of an equivalence class. The findings from the present experiment extend the literature by showing the class-enhancing effect of meaningful stimuli in large equivalence class formation. Thus, whereas yields of class formation is about 80% in PIC groups for three 5-member classes, yields of class formation were 50% in the present experiment indicating a reduction in the class-enhancing effect of meaningful stimuli as the number of members in a to-be-formed class increases from five to seven. This drop can be explained as a function of the number of nodes. With this finding, it is imperative that in applied settings, optimal results for the meaningful stimulus can be obtained by the adoption of other training structures such as the MTO or OTM in conditional-discrimination training with larger classes because these training structures limit the effect of the number of nodes in tests for emergent relations.

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Data Availability The data for this study cannot be shared due to ethical reasons. Participants in the study did not consent to sharing their data with other persons outside the researchers who conducted the study.

Declarations

Conflict of Interest The authors declare that there is no conflict of interest.

Ethical approval 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 Informed consent was obtained from all individual participants included in the experiment.

References

Arntzen, E. (2004). Probability of equivalence formation: Familiar stimuli and training sequence. *The Psychological Record, 54*(2), 275–291. https://doi.org/10.1007/BF03395474.

Arntzen, E. (2012). Training and testing parameters in formation of stimulus equivalence: Methodological issues. *European Journal of Behavior Analysis, 13*(1), 123–135. https://doi.org/10.1080/15021149.2012.11434412.

Arntzen, E., Dechsling, A., & Fields, L. (2021). Expansion of arbitrary stimulus classes measured by sorting performances. *Journal of the Experimental Analysis of Behavior, 115*(1), 326–339.

Arntzen, E., & Eilertsen, J. M. (2020). using stimulus-equivalence technology to teach skills about nutritional content. *Perspectives on Behavior Science, 43*, 469–485. https://doi.org/10.1007/s40614-020-00250-2.

Arntzen, E., Granmo, S., & Fields, L. (2017). The relation between sorting tests and matching-to-sample tests in the formation of equivalence classes. *The Psychological Record, 67*(1), 81–96. https://doi.org/10.1007/s40732-016-0209-9.

Arntzen, E., Grondahl, T., & Eilifsen, C. (2010). The effects of different training structures in the establishment of conditional discriminations and subsequent performance on tests for stimulus equivalence. *The Psychological Record, 60*(3), 437–462. https://doi.org/10.1007/BF03395720.

Arntzen, E., & Hansen, S. (2011). Training structures and the formation of equivalence classes. *European Journal of Behavior Analysis, 12*(2), 483–503. https://doi.org/10.1080/15021149.2011.11434397.

Arntzen, E., & Holth, P. (1997). Probability of stimulus equivalence as a function of training design. *The Psychological Record, 47*(2), 309–320. https://doi.org/10.1007/BF03395227.

Arntzen, E., & Holth, P. (2000). Equivalence outcome in single subjects as a function of training structure. *The Psychological Record, 50*(4), 603–628. https://doi.org/10.1007/BF03395374.

Arntzen, E., & Lian, T. (2010). Trained and derived relations with pictures as nodes. *The Psychological Record, 60*(4), 659–677. https://doi.org/10.1007/BF03395738.

Arntzen, E., & Mensah, J. (2020). On the effectiveness of including meaningful pictures in the formation of equivalence classes. *Journal of the Experimental Analysis of Behavior, 113*(2), 305–321. https://doi.org/10.1002/jeab.579.

Arntzen, E., & Nartey, R. K. (2018). Equivalence class formation as a function of preliminary training with pictorial stimuli. *Journal of the Experimental Analysis of Behavior, 110*(2), 275–291. https://doi.org/10.1002/jeab.466.

Arntzen, E., Nartey, R. K., & Fields, L. (2014). Identity and delay functions of meaningful stimuli: enhanced equivalence class formation. *The Psychological Record, 64*(3), 349–360. https://doi.org/10.1007/s40732-014-0066-3.

Arntzen, E., Nartey, R. K., & Fields, L. (2015a). Enhanced equivalence class formation by the delay and relational functions of meaningful stimuli. *Journal of the Experimental Analysis of Behavior, 103*(3), 524–541. https://doi.org/10.1002/jeab.152.

Arntzen, E., Nartey, R. K., & Fields, L. (2018a). Graded delay, enhanced equivalence class formation, and meaning. *The Psychological Record, 68*(2), 123–140. https://doi.org/10.1007/s40732-018-0271-6.

Arntzen, E., Nartey, R. K., & Fields, L. (2018b). Reorganization of equivalence classes: Effects of preliminary training and meaningful stimuli. *Journal of the Experimental Analysis of Behavior, 109*(3), 564–5586. https://doi.org/10.1002/jeab.329.

Arntzen, E., Norbom, A., & Fields, L. (2015b). Sorting: An alternative measure of class formation? *The Psychological Record, 65*(4), 615–625. https://doi.org/10.1007/s40732-015-0132-5.

Bentall, R. P., Dickins, D. W., & Fox, S. R. A. (1993). Naming and equivalence: Response latencies for emergent relations. *Quarterly Journal of Experimental Psychology, 46*(2), 187–214. https://doi.org/10.1080/14640749308401085.

Buffington, D. M., Fields, L., & Adams, B. J. (1997). Enhancing equivalence class formation by pretraining of other equivalence classes. *The Psychological Record, 47*(1), 69–96. https://doi.org/10.1007/BF03395213.

Fields, L., Adams, B. J., & Verhave, T. (1993). The effects of equivalence class structure on test performaces. *The Psychological Record, 43*(4), 697–721. https://doi.org/10.1007/BF03395907.

Fields, L., Arntzen, E. & Doran, E. (2020). Yield as an essential measure of equivalence class formation, other measures, and new determinants. *The Psychological Record, 70*,175–186. https://doi.org/10.1007/s40732-020-00377-3.

Fields, L., Arntzen, E., & Moksness, M. (2014). Stimulus sorting: A quick and sensitive index of equivalence class formation. *The Psychological Record, 64*(3), 487–498. https://doi.org/10.1007/s40732-014-0034-y.

Fields, L., Arntzen, E., Nartey, R. K., & Eilifsen, C. (2012). Effects of a meaningful, a discriminative, and a meaningless stimulus on equivalence class formation. *Journal of the Experimental Analysis of Behavior, 97*(2), 163–181. https://doi.org/10.1901/jeab.2012.97-163.

Fields, L., Paone, D. (2020). Training modality and equivalence class formation under the simultaneous protocol: A test of stimulus control topography coherence theory. *The Psychological Record 70*, 293–305. https://doi.org/10.1007/s40732-020-00384-4.

Fields, L., Reeve, K., Rosen, D., Varelas, A., & Adams, B. (1997). Using the simultaneous protocol to study equivalence class formation: The facilitating effects of nodal number and size of previously established equivalence classes. *Journal of the Experimental Analysis of Behavior, 67*(3), 367–389. https://doi.org/10.1901/jeab.1997.67-367.

Fields, L., & Verhave, T. (1987). The structure of equivalence classes. *Journal of the Experimental Analysis of Behavior, 48*(2), 317–332. https://doi.org/10.1901/jeab.1987.48-317.

Holth, P., & Arntzen, E. (1998). Stimulus familiarity and the delayed emergence of stimulus equivalence or consistence nonequivalence. *The Psychological Record, 48*(1), 81–110. https://doi.org/10.1007/BF03395260.

Kennedy, C. H. (1991). Equivalence class formation influenced by the number of nodes separating stimuli. *Behavioural Processes, 24*, 219–245.

McIlvane, W. J., & Dube, W. V. (1992). Stimulus control shaping and stimulus control topographies. *The Behavior Analyst, 15*(1), 89–94. https://doi.org/10.1007/BF03392591.

Mensah, J., & Arntzen, E. (2017). Effects of meaningful stimuli contained in different numbers of classes on equivalence class formation. *The Psychological Record, 67*(3), 325–336. https://doi.org/10.1007/s40732-016-0215-y.

Nartey, R. K., Arntzen, E., & Fields, L. (2014). Two discriminative functions of meaningful stimuli that enhance equivalence class formation. *The Psychological Record, 64*(4), 777–789. https://doi.org/10.1007/s40732-014-0072-5.

Nartey, R. K., Arntzen, E., & Fields, L. (2015a). Enhancement of equivalence class formation by pretraining discriminative functions. *Learning & Behavior, 43*(1), 20–31. https://doi.org/10.3758/s13420-014-0158-6.

Nartey, R. K., Arntzen, E., & Fields, L. (2015b). Training order and structural location of meaningful stimuli: effects on equivalence class formation. *Learning & Behavior, 43*(4), 342–353. https://doi.org/10.3758/s13420-015-0183-0.

Nedelcu, R. I., Fields, L., & Arntzen, E. (2015). Arbitrary conditional discriminative functions of meaningful stimuli and enhanced equivalence class formation. *Journal of the Experimental Analysis of Behavior, 103*(2), 349–360. https://doi.org/10.1002/jeab.141.

Saunders, K. J., Saunders, R. R., Williams, D. C., & Spradlin, J. E. (1993). An interaction of instructions and training designs on stimulus class formation: Extending the analysis of equivalence. *The Psychological Record, 43*(4), 725–744. https://doi.org/10.1007/BF03395909.

Saunders, R. R., Chaney, L., & Marquis, J. G. (2005). Equivalence class establishment with two-, three-, and four-choice matching to sample by senior citizens. *The Psychological Record, 55*(4), 539–559. https://doi.org/10.1007/bf03395526.

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*(1), 117–137. https://doi.org/10.1901/jeab.1999.72-117.

Sidman, M. (1994). Equivalence relations and behavior: A research story. Boston: Authors Cooperativ

Sidman, M., & Tailby, W. (1982). Conditional discrimination vs. matching to sample: an expansion of the testing paradigm. *Journal of the Experimental Analysis of Behavior, 37*(1), 5–22. https://doi.org/10.1901/jeab.1982.37-5.

Travis, R. W., Fields, L., & Arntzen, E. (2014). Discriminative functions and over-training as class-enhancing determinants of meaningful stimuli. *Journal of the Experimental Analysis of Behavior, 102*(1), 47–65. https://doi.org/10.1002/jeab.91.

Wulfert, E., Dougher, M. J., & Greenway, D. E. (1991). Protocol analysis of the correspondence of verbal behavior and equivalence class formation. *Journal of the Experimental Analysis of Behavior, 56*, 489–504. https://doi.org/10.1901/jeab.1991.56-489.