Generalized contextual control based on nonarbitrary and arbitrary transfer of stimulus functions

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Abstract

Two experiments with human adults investigated the extent to which the transfer of function in accordance with non-arbitrary versus arbitrary stimulus relations may be brought under contextual control. Experiment 1 comprised four phases. Phase 1 consisted of multiple exemplar training to establish discriminative functions for solid, dashed, or dotted lines. Phase 2 trained and tested two equivalence classes each containing a 3D picture, a solid, a dashed, and a dotted form. During Phase 3 a discriminative function was established for each 3D picture. Phase 4 presented the solid, dashed, and dotted stimuli in two different frames, black or gray. The black frame cued function transfer based on non-arbitrary stimulus relations (Frame Physical); the gray frame cued function transfer based on equivalence relations (Frame Arbitrary). Testing and training with the frames was continued until contextual control was established; subsequently contextual control was demonstrated with novel equivalence classes with stimuli composed of the same forms. Experiment 2 replicated and extended Experiment 1 by demonstrating that such contextual control generalized to novel equivalence classes comprised of novel forms and responses. The potential implications of the findings for developing increasingly precise experimental analyses of clinically relevant phenomena are considered.

Keywords: equivalence relations, contextual control, transfer of function, multiple-exemplar training, adults.

Generalized Contextual Control Based on Non-arbitrary and Arbitrary Transfer of Stimulus Functions

Verbally competent humans are not only able to respond to complex arbitrary relations between stimuli given appropriate training, but are also fluent in responding to novel and multiple stimulus relations that derive from those previously trained. For instance, after learning AB and BC relations, the participants are likely to respond correctly to novel relations that are related by symmetry, such as BA and BC, and also to novel combinations of stimulus relations that cohere with the original training set, such as the case for transitivity AC and CA (symmetrical transitivity). Such phenomena, named derived relational responding, have supported a contemporary behavioral approach to language and cognition (e.g., Hayes, Fox et al., 2001; Sidman, 1994).

Another important feature of responding based on arbitrary relations is the transfer of function, which is the indirect acquisition of stimulus functions via equivalence relations among stimuli (e.g., Dougher et al., 1994; for a review, see Dymond & Rehfeldt, 2000). For example, after forming an equivalence class consisting of A-B-C stimuli, if A is established via differential reinforcement as discriminative for a given response, the other stimuli related via equivalence will indirectly acquire a similar function (i.e., will affect behavior in a similar manner as A). The transfer of a variety of stimulus functions has already been documented, such as discriminative (e.g., de Rose, McIlvane et al., 1988; Perez et al., 2021; Perez, Fidalgo et al., 2015), eliciting (e.g., Dougher et al., 1994; Luciano et al., 2014), consequential (Hayes et al., 1991), extinction (Dougher et al., 1994), and contextual (Gatch & Osborne, 1989; Perez et al., 2017; 2021; Perez, Fidalgo et al., 2015).

Transfer of function has been extensively documented across studies that typically show a single stimulus function spreading through an established equivalence class, with some research demonstrating potential uses in applied settings (e.g., Murphy et al., 2005; Rosales & Rehfeldt, 2007). Nonetheless, outside the laboratory, stimuli typically have multiple functions, rather than a single function. Thus, as many researchers have suggested, the contextual control of stimulus functions is a key feature for a behavioral account of human language (Bush et al., 1989; Dougher et al., 2002; Hayes et al., 2001; Hayes & Hayes, 1992; Perez et al., 2017, 2021; Perez, Fidalgo et al., 2015; Perkins et al., 2007; Sidman, 1986, 1992, 1994). Contextual control is necessary to specify and delimit the stimulus functions that are operative or appropriate for a given situation (e.g., Barnes et al., 1995; Dougher et al., 2002; Perez, Fidalgo et al., 2015; Perez et al., 2021; Perkins et al., 2007). For instance, while the presence of a loaf of bread may elicit salivation, evoke eating, and occasion saying the word “bread,” only two of those functions (i.e., salivation and saying the word) would be appropriate in the presence of pictures of bread or the word, “bread”. While eating bread is often reinforcing, little reinforcement is available for attempting to eat pictures or words.

Relational Frame Theory (RFT; Hayes et al., 2001) denotes the contextual stimuli that are established to specify stimulus functions operating in particular situations as Cfuncs (see Hayes, Fox et al., 2001, p. 33). Perez, Fidalgo et al. (2015) investigated Cfunc control with adult participants (see Barnes et al., 1995 for a similar study with children). Initially, five-member equivalence classes (A1-B1-C1-D1-E1 and A2-B2-C2-D2-E2) were established. Participants then learned different key-pressing responses in the presence of the B stimuli, depending on the background color on the computer monitor (Blue/B1-press X, Blue/B2-press Z, Yellow/B1-press M, Yellow/B2-press N). In a transfer-of-function test, the C, D and E stimuli were presented on the different colored backgrounds. Results demonstrated that the colored backgrounds functioned as Cfunc stimuli, controlling the participants' key-pressing responses in the presence of any stimulus from the five-member equivalence network (e.g., Blue/C1-press X, Blue/C2-press Z, Yellow/C1-press M, Yellow/C2-press N). This study showed how multiple functions might come under the control of other stimuli that establish the appropriate occasion for differential responses. Similar results were found in Perez et al. (2021) using different response topographies established under positive and negative reinforcement, and an additional context for extinction.

As noted above, contextual control is also important, in some cases, to delimit which stimulus functions transfer and, hence, which responses occur in particular contexts. For example, Dougher et al. (2002) established a context in which responding in line with transfer of functions was reinforced and another in which it was punished. Thus, the contextual control over function transformation meant contingencies of reinforcement contextually controlled which behaviors occurred in the presence of a given member of an equivalence class. Adult participants were exposed to a MTS task that aimed to establish three five-member equivalence classes, A1-B1-C1-D1-E1, A2-B2-C2-D2-E2 and A3-B3-C3-D3-E3. Next, specific stimulus functions were established for stimuli B1, B2, and B3 (e.g., sequencing). After that, equivalent stimuli (e.g., C1, C2, C3) were presented on a red or a blue background. When the background color was red, class-consistent derived responses (transfer of function) were reinforced (i.e., respond to C1 as trained for B1; respond to C2 as trained for B2, etc.). In contrast, when the background was blue, responses in accordance with transfer of function were punished. As multiple-exemplar training with different types of responses progressed (e.g., key choice, color sorting), transfer of function occurred in the presence of the red background but not in the presence of the blue. Perkins et al. (2007) systematically replicated that study and also found that responding in line with transfer of function may be reinforced and punished for specific stimuli of a given class (for instance, transfer to B stimuli but not to stimulus set D)[1].

According to Perkins et al. (2007), although different researchers have assumed contextual control of transfer of function, few studies have directly investigated this topic (Dougher et al., 2002; Perez, Fidalgo et al., 2015; Perez et al., 2017; Perkins et al., 2007). One area that seems important to explore is the extent to which the transfer of function in accordance with stimulus relations that are non-arbitrary (i.e., based solely on the formal or physical properties of the stimuli) versus arbitrary (i.e., involving symbolic or derived properties, such as word-referent relations) may be brought under contextual control. These types of contextual control may be relevant for applied purposes in therapy. Acceptance and commitment therapy (ACT; Hayes et al., 2012), for instance, has argued that undermining or disrupting the contextual control over derived transfers of function

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[1] Strictly speaking, a transfer of function is not directly reinforced or punished because, by definition, transfer of function must occur in the absence of differential consequences for a specific transfer. What is reinforced/punished, however, is contextual (i.e., generalized) control over the transfer of functions. For example, having reinforced contextual control over the transfer of functions in one equivalence class, the same contextual control may then be observed in a second equivalence class in the absence of differential reinforcement. In this sense, contextually controlled transfer of function itself may be conceptualized as part of the generalized operant of arbitrarily applicable relational responding (AARR; Barnes-Holmes & Harte, 2022a; see also Dymond & Barnes, 1995).

is a critical feature of what have been referred to as defusion interventions (i.e., therapeutic exercises that aim to undermine the aversive but not semantic functions of verbal stimuli). Indeed, the distinction between the evoking (e.g., emotional) versus relational (e.g., semantic) properties of equivalence classes and other derived relations has been highlighted as potentially important for a more precise analysis of the concept of defusion itself (Harte et al., 2022); we shall return to this issue in the General Discussion.

The purpose of Experiment 1 was to extend the findings of Perez and colleagues (Perez, Fidalgo et al. 2015; Perez et al., 2021), who showed the contextual control of multiple stimulus functions within an equivalence class, and Dougher et al. (2002) and Perkins et al. (2007) who showed the contextual control of transfer of function itself. Specifically, the present study aimed to investigate the contextual control over the derived transfer of functions based on either non-arbitrary (physical) stimulus control or derived (arbitrary) stimulus relations.

EXPERIMENT 1

Method

Participants

Four verbally competent adults (1 male and 3 females), ranging in age from 26-29 years, took part in the experiment. They were recruited by personal contacts. Before the experiment began, participants read and agreed to specific terms of consent (approved by the Brazilian platform for ethical committees, Plataforma Brasil, CAAE 65275717.0.0000.8054, #2.045.850). At the end of the experimental sessions, participants were fully debriefed concerning the goals of the experiment and procedural issues under consideration. They received no payment or compensation for participating in the research.

Setting, Equipment and Stimuli

The experimental sessions took place in a quiet room (3 x 4 m) equipped with a table, a chair and a laptop computer. Custom-written software in Visual Basic 6.0 (RelationalFraming - Perez, 2014; Key-pressing Task – Perez, 2015) presented stimuli, delivered consequences and recorded participants' responses. As depicted in Figure 1, stimuli consisted of pictures of abstract colorful 3D objects and forms (possibly unknown for the participant) and different forms composed of solid, dashed or dotted lines. Throughout training trials, experimenter-designated correct responses were followed by the presentation of the word "CORRECT" (Arial 16) on the center of the screen and an ascending sequence of musical notes (1 s) as consequences; incorrect responses produced the presentation of the word "INCORRECT" (Arial 16) and a dissonant sound (1 s).

Procedure

Experiment Overview. Given the complexity of the current experimental preparation, a brief summary of the overall procedure is first presented here and in Figure 2. The complete details of each phase will be then be presented in specific sections relevant to those phases.

Experimental procedures were divided into four phases. Phase 1 consisted of multiple exemplar training that aimed to establish discriminative functions for stimuli comprised of solid, dashed or dotted lines (solid press A; dashed press S; dotted press D on the keyboard). Phase 2 aimed to train and test two equivalence classes (e.g., A1-B1-C1-D1 and A2-B2-C2-D2), each consisting of a 3D picture (e.g., A1 and A2), a solid (e.g., B1 and B2), a dashed (e.g., C1 and C2) and a dotted form (e.g., D1 and D2; see also Figure 1).

During Phase 3, the two 3D pictures (i.e., A1 and A2) were given particular discriminative functions (i.e., A1 press F; A2 press G). Finally, Phase 4 presented the solid, dashed and dotted stimuli on two different frames, black or gray. The intent was to establish one of the frames as the occasion for responding under control of the physical properties of the stimuli, as in Phase 1 (solid press A; dashed press S; dotted press D) and the other frame as the occasion for responses based on equivalence relations (i.e., transfer of function) with the 3D pictures, established during Phase 2 (B1, C1 or D1 press F; B2, C2 or D2 press G).

After Phase 1, participants progressed through multiple cycles of exemplar training. Specifically, participants advanced from Phase 2 through Phase 4 with the first stimulus set (Cycle 1; see Figure 2). In Phase 4, test trials were presented first. If the frames did not evoke the appropriate response, training contingencies were programmed to establish contextual control over the derived transfer of functions based on either non-arbitrary (Frame Physical) or arbitrary (Frame Arbitrary) stimulus relations for that particular stimulus set. Then, the participant started another cycle of training and testing from Phase 2 through Phase 4, with another stimulus set (i.e., novel 3D pictures, solid, dashed and dotted forms; see Figure 1 and 2, Cycles 2, 3 etc.) until contextual control by the black and gray frames was demonstrated during Phase 4 testing.

Phase 1. Establishing stimulus functions based on physical properties. Participants were submitted to a simple successive discrimination task. Before starting, participants read minimal instructions on how to perform the task and what keys on the keyboard should be used in that phase: “*A picture will appear at the top of the screen. Your goal is to learn which key on the keyboard to press for each type of figure presented. You can use the rows of letters between A and L and also between Z and M on the keyboard. There is only one correct answer for each type of figure. The computer will give you feedback whether your answer was correct or not.*”

Each trial began with the presentation of a stimulus at the center of the screen, which could be a solid, dashed or dotted line form, randomly presented from a pool of 18 different stimuli, six for each line type. Experimenter-designated correct responses were: (1) pressing the A key given a solid line form; (2) pressing the S key given a dashed line form and (3) pressing the D key given a dotted line form. Responses were followed by programmed consequences for correct (“CORRECT!” + ascendent sound) and incorrect responding (“INCORRECT” + dissonant sound), a 1.5-s intertrial interval (ITI, blank screen) and the next trial onset. Training trials ended once participants met the mastery criteria of 24 consecutive correct responses. After that, a test was conducted in which 3 novel stimuli of each line type were presented twice in an 18-test trial block without feedback; responses were followed only by the ITI and the next trial onset. Before the test block started, participants read the following instruction on the screen: “*From now on, the computer will no longer present feedback for your choices. Yet, it will keep recording your hits and errors*”. This phase ended if participants emitted 17/18 correct responses during the test (> 90%). Otherwise, they restarted Phase 1 training followed by retesting.

Phase 2. Establishing two four-member equivalence classes. During this phase, participants were exposed to a matching-to-sample (MTS) task that aimed to establish two four-member equivalence classes comprised of a 3D picture, a solid, a dashed, and a dotted form. Participants were given minimal instruction on how to perform the task using the computer trackpad: "*Some figures will be presented on the monitor screen. Each trial will begin with a figure presented in the center. After you click on it, three other figures will appear in the corners and only one must be chosen. To choose a given figure, just click on it. Correct choices will be followed by a soft sound and the word CORRECT; incorrect choices will be followed by a dissonant sound and the word INCORRECT. As you progress in this task, there will be a moment when the computer will no longer give you any feedback. However, it will keep recording your responses, evaluating your hits and errors*."

Each trial began with the onset of a sample stimulus at the center of the screen (e.g., A1). After a 1-s interval, three adjacent comparison stimuli were presented across the lower portion of the screen. One click on the comparison stimulus designated to belong to the same class as the sample (e.g., B1) was followed by programmed consequences for correct responding; clicking on any other comparison stimuli (e.g., B2 or Bx) was followed by programmed consequences for incorrect responding. The delivery of consequences was immediately followed by a 1.5-s ITI (blank screen) and the next trial onset.

During Cycle 1, stimulus sets A, B, C and D were used to form the equivalence classes A1-B1-C1-D1 and A2-B2-C2-D2, as depicted in Figures 1 and 2. Considering that linear straining structure is the least effective to establish equivalence classes (e.g., Arntzen & Hanssen, 2011) the present study implemented a mixed AB+AC+CD training structure, which has proved effective in several studies (e.g., Bortoloti & de Rose, 2009; Perez et al., 2019, 2020, 2021; Perez, Fidalgo et al., 2015). This structure has the advantage of allowing a combined test for transitivity and symmetry based on only two relations, BD and DB. Accurate performance in these relations logically requires that the trained relations possess the properties of symmetry and transitivity (cf. Sidman, 1994, p. 224). We dispensed with tests of reflexivity based on Saunders and Green (1992), who argued that results of such tests may be confused with generalized identity matching.

The training of conditional relations among stimulus sets was divided into four blocks. The first block taught AB relations (A1-B1 and A2-B2). Each trial began with the presentation of A1 or A2 as sample stimuli and B1, B2 and Bx as comparison stimuli. A third comparison stimulus, Bx, was used to decrease the likelihood of responses based on sample/S- relations (Sidman, 1987; Perez & Tomanari, 2015), but was never programmed as a correct option (S+) for any of the sample stimuli. The presentation of the stimuli in each trial was semi-randomly programmed so that: (1) the same sample was not presented more than 3 times consecutively and, similarly; (2) the comparison stimuli were not presented in the same location more than 3 times consecutively. The training block ended once the participant emitted 12 consecutive correct responses. The following training blocks had the same parameters. They trained relations AC (A1-C1 and A2-C2) and CD (C1-D1 and C2-D2). Once the participant had learned AB, AC and CD conditional relations separately, training trials from all training blocks were mixed in a AB+AC+CD training block until participants met the mastery criterion of 36 consecutive correct responses. After that, equivalence tests began.

Before test trials, participants were instructed as in Phase 1 testing. BD relations were tested first. Ten BD test trials, 5 for each relation (B1-D1 and B2-D2) were randomly presented. Participant’s responses had no differential feedback, being followed only by the ITI and the next trial onset. DB relations were tested next (D1-B1 and D2-B2) using the same parameters described for BD testing. Criterion for ending Cycle 1 of Phase 2 and progressing for Phase 3 was at least 90% correct responses on BD and DB tests. If performance was below criterion, the mixed AB+AC+CD training was repeated and followed by retesting (however, this was unnecessary for all participants).

During Cycle 2, stimulus sets E, F, G and H were used to form the following classes: E1-F1-G1-H1 and E2-F2-G2-H2. Using the same parameters described for Cycle 1, EF, EG and GH relations were trained in this order, followed by a mixed EF+EG+GH training block and FH and HF equivalence tests. Stimulus sets used on further cycles are presented in Figure 1.

Phase 3. Establishing an arbitrary function for the 3D pictures. The experimental task used in this phase was the same as described in Phase 1. This experimental phase aimed to establish discriminative functions for the 3D pictures belonging to each of the two equivalence classes. During Cycle 1, participants were taught A1 press F and A2 press G (see Figure 1 and Figure 2). A1 and A2 were randomly presented until participants met the mastery criterion of 16 consecutive correct responses. After that, Cycle 1 Phase 3 ended and participants started on Cycle 1 Phase 4. Stimuli and designated correct responses across the multiple cycles are presented in Figures 1 and 2.

Phase 4. Testing (and training) contextual control of transfer of functions based on non-arbitrary and arbitrary stimulus relations. The experimental task used in this phase was the same as described in Phases 1 and 3. However, stimuli were presented within either a black or a gray frame. This experimental phase aimed to test whether these two different frames around the solid, dashed, and dotted stimuli from the two previously established equivalence classes would exert contextual control over the transfer of functions based on non-arbitrary and arbitrary stimulus relations. For two participants (P1 and P2), whenever the stimuli were presented in a black frame (Frame Physical), responses based on physical properties were considered correct, as trained in Phase 1; whenever the stimuli were presented in a gray frame (Frame Arbitrary), responses based on arbitrary stimulus (equivalence) relations with the 3D pictures (trained during Phase 2 and 3), were considered correct. For two other participants (P3 and P4), the role of the frames was reversed: Frame Physical was gray and Frame Arbitrary was black. For example, in Cycle 1, responses considered correct given Frame Physical were: B1 or B2 (solid) press A; C1 or C2 (dashed) press S; D1 or D2 (dotted) press D. When the stimuli were presented in Frame Arbitrary, correct responding was determined by the class membership of the stimuli: B1, C1, or D1 press F (as trained for A1) and B2, C2, or D2 press G (as trained for A2).

Before starting Cycle 1 testing with the frames, B1, B2, C1, C2, D1 and D2 stimuli were presented without frames three times each in a simple 18-trial transfer of function test. This test served as a baseline measure of whether participant's responses would be under control of equivalence relations with A1 and A2 or under the control of the physical properties of B, C and D stimuli. This test was exclusive for Cycle 1. After that, testing was the same during all cycles. Phase 4 began with a 48-trial test block with no feedback for participant's responses. During this test, the solid, dashed and dotted stimuli used on that cycle were presented in half of the trials on each of the two frames, Frame Physical and Frame Arbitrary. For example, In Cycle 1, B1, B2, C1, C2, D1, and D2 were presented each four times within a black frame and four times within a gray frame. In Phase 4, the presentation of the stimuli in each trial was randomized and followed the same parameters described for Phase 1. If a participant emitted ≥ 93% correct responses, the experiment ended and the computer presented a message "*Please, call the experimenter*". If a participant emitted < 93% correct responses, all test trials were then converted to training trials, with programmed consequences for correct and incorrect responding. These training trials involved both frames and were presented until participants emitted 36 consecutive correct responses. After that, the participant started another cycle, from Phase 2 to Phase 4, with novel stimulus sets. The number of experimental cycles to establish contextual control based on non-arbitrary and arbitrary stimulus relations were as many as necessary for the participant to meet the mastery criterion on Phase 4 testing.

Results and Discussion

Table 1 presents results from the four participants across the experimental phases. Results from training are the number of trials to meet the mastery criterion; results from tests are the percentage of correct responses. In Phase 1 training (responding to physical properties), participants required between 34 to 76 trials to meet the mastery criterion; during testing with novel stimuli, all participants scored 100%. In Phase 2 training (to establish equivalence relations), the total number of trials to learn the conditional relations between all stimulus sets was similar for all participants across cycles; during testing of equivalence relations, all participants scored 100% throughout the cycles. In Phase 3 (establishing an arbitrary function to the 3D pictures), participants required between 16 to 21 trials to learn the correct key-pressing response in the presence of the 3D pictures. Phase 4, which assessed or trained contextual control by the frames, started with a test without frames. In this test, responses based on the transfer of functions (based on equivalence relations) were arbitrarily designated as correct. Responding in this test varied among participants. P1 had no consistent pattern of responding; responses from P2 and P3 were controlled by the physical properties of the stimuli, as in Phase 1; responses from P4 were based on the equivalence relations with the 3D pictures, as in Phase 2.

During the first test with the frames (Cycle 1), as expected, participants' responses were at chance (50%). P1 started responding based on the physical properties and then moved to responses based on derived equivalence relations. Responses by P2 and P3 responses were always controlled by the physical properties of the stimuli; P4 produced no consistent pattern of responding. After that, participants were given training trials with the frames and required between 42 and 285 trials to achieve the mastery criterion. During Cycle 2 testing with the frames (Phase 4), all four participants rapidly met the mastery criterion suggesting contextual control of the frames over the transfer of function based on non-arbitrary or arbitrary stimulus relations.

Although all participants met the necessary criterion by the end of Cycle 2, we decided to run Cycle 3, so that testing could occur with a novel set of stimuli. The participants were first retrained with the frames at the end of Cycle 2, and then progressed to Cycle 3. During Cycle 3 testing with the frames (Phase 4), participants’ responding was highly accurate, as in Cycle 2, documenting contextual control once more.

Experiment 1 aimed to establish contextual control over the transfer of functions based on non-arbitrary or arbitrary stimulus relations. The participants rapidly progressed through the experimental phases and after a first exposure to differential consequences for responding in Frame Physical and Frame Arbitrary (Cycle 1), they demonstrated contextual control with novel equivalence classes established in Cycle 2. Their performance was maintained during tests with a third set of novel equivalence classes (Cycle 3).

As observed in previous studies, the contextual control of transfer of function was successfully established for all participants (see Dougher et al., 2002; Perkins et al., 2007). Only two cycles of exemplar training were sufficient for participants to meet the test criterion. The present results extend previous findings on contextual control of multiple stimulus functions in equivalence classes. Specifically, Perez et al. (2021) showed contextual control over derived responses initially established via positive reinforcement, negative reinforcement and, additionally, derived extinction. The present study, however, showed contextual control over two different sources of stimulus functions, one based on the physical non-arbitrary properties of the stimuli and the other based on arbitrary (equivalence) relations.

An issue that remained unanswered in Experiment 1, however, concerns the extent to which the observed contextual control could be maintained. The fact that frames functioned as contextual stimuli across the experimental cycles might have depended on the characteristics of the task that remained constant. For example, equivalence classes always comprised stimuli with similar characteristics. One could argue, therefore, that the contextual control of stimulus functions observed in Experiment 1 may be interpreted as a type of compound conditional control; in other words, the function of the frames merged with the members of the equivalence classes themselves (e.g., Meehan & Fields, 1995; Modenesi & Debert, 2015; Stromer et al., 1993). As pointed out by Dougher et al. (2002), “to demonstrate contextual control unambiguously, contextual control… must be demonstrated over stimuli that were not used to train contextual control. Only then can the possibility of compound- stimulus control be ruled out.” (p. 65). This issue was pursued in Experiment 2.

EXPERIMENT 2

Method

Participants

Participants were three verbally competent adults (2 males and 1 female) ranging in age from 24-30 years. Recruitment and ethical procedures followed the description presented for Experiment 1.

Setting, Equipment and Stimuli

Setting, equipment, and stimuli were as described for Experiment 1. Additional stimuli presented in the generalization test are depicted in Figure 3: nonsense words, blue, yellow, and red forms.

Procedure

The initial phases of Experiment 2 were a direct replication of Experiment 1. That is, participants were exposed to Phase 1 and then to multiple cycles from Phases 2-4 until contextual control over the transfer of functions based on non-arbitrary or arbitrary stimulus relations was observed. After that, generalized contextual control was assessed with novel stimulus sets and response functions.

Direct replication of Experiment 1. Experimental phases were as described in Experiment 1. Experiment 2 proper started once participants passed Phase 4 testing. For P5 and P6, the black frame was programed as Frame Physical and the gray frame as Frame Arbitrary. For P7, the contingencies regarding the frames were reversed (black = Frame Arbitrary; gray = Frame Physical).

Phase 5. Establishing stimulus functions based on novel physical properties. Phase 5 established responses under control of a novel physical property. This allowed evaluating the extension of contextual control to stimulus features that were not present in the same preparation in which the contextual functions of the frames were trained.

Before starting, the participants read the following instructions on the screen: *"A picture will appear at the top of the screen. Your goal is to learn which key on the keyboard to press for each type of figure presented. You can use the row of numbers between 1 and 0 on the keyboard. There is only one correct answer for each type of figure. The computer will give you feedback whether your answer was correct or not*."

Each trial began with the presentation of a stimulus on the center of the screen, which could be a blue, yellow, or red form, randomly presented from a pool of 18 different stimuli, six for each color. Experimenter-designated correct responses were: (1) pressing key 1 on the keyboard given a blue form; (2) pressing key 2 given a yellow form; and (3) pressing key 3 given a red form. After training, a test presented three novel stimuli of each color twice in a 18-test trial block. Training and testing parameters were the same as described for Phase 1 of Experiment 1.

Phase 6. Establishing novel equivalence classes. Phase 6 aimed to establish two four-member equivalence classes (W1-X1-Y1-Z1 and W2-X2-Y2-Z2) each comprising a nonsense word (W1 or W2), a blue (X1 or X2), a yellow (Y1 or Y2), and a red form (Z1 or Z2), as depicted in Figure 3. Training and testing parameters were the same as described in Phase 2 of Experiment 1.

Phase 7. Establishing an arbitrary function to the nonsense words. This experimental phase aimed to establish discriminative functions for the nonsense words belonging to each of the two equivalence classes. Participants were taught W1 press 4 and W2 press 5 (see Figure 3). The experimental task and parameters used on trials from this phase were the same as described for Phase 3 of Experiment 1.

Phase 8. Testing generalized contextual control over the transfer of functions based on non-arbitrary and arbitrary stimulus relations. This experimental phase aimed to test generalized contextual control over non-arbitrary and arbitrary stimulus relation function transfer. Thus, stimuli used in Phases 6 and 7 were presented within Frame Physical and Frame Arbitrary. Parameters used during this phase were the same described in Phase 4 testing of Experiment 1.

Results and Discussion

Table 2 presents results from the direct replication of Experiment 1 in terms of the number of trials to meet mastery criterion during training trials and the percentage of correct responses during test trials. In Phase 1 training (establishing responses under control of solid, dashed, and dotted physical properties), participants (P5, P6 and P7) required between 38 and 77 trials to meet mastery criterion; during testing with novel stimuli, all participants scored 100% correct. In

Phase 2 (equivalence training and testing), the total number of trials to learn the conditional relations between all stimulus sets ranged from 84-100 across cycles; during testing of equivalence relations all participants scored high, from 95-100% correct throughout the cycles.

In Phase 3 (establishing an arbitrary function for the 3D pictures) participants required between 17 and 33 trials to learn the correct key-pressing response in the presence of the 3D pictures. Responses during Phase 4 (testing without the frames) varied from 0-31% correct. Note that in this phase, responses based on (derived) transfer of function were considered as correct. Thus, the participants appeared to respond mostly based on non-arbitrary (physical) stimulus relations. During the first test with the frames (Cycle 1), as expected, participants' responses were close to chance (50%). After that, during training trials with the frames, the participants required between 98 and 130 trials to achieve mastery criterion. During Cycle 2 of testing with the frames (Phase 4), P6 and P7 met mastery criterion suggesting contextual control of the frames over derived transfer based on non-arbitrary and arbitrary stimulus relations; P5 attained criterion during Cycle 3, when all participants scored 100% of correct responses.

Table 3 presents results from testing of generalized contextual control over derived transfer based on non-arbitrary and arbitrary stimulus relations in Experiment 2. During Phase 5 (that trained specific responses under control of stimulus colors), all participants learned to respond under the control of stimulus colors, needing from 24-30 trials to attain mastery criterion and responding correctly with novel exemplars with the same colors during tests. During Phase 6 (equivalence training and testing with nonsense words and colored stimuli), participants required between 75 and 83 trials to reach mastery criterion for conditional relations involving nonsense words, blue, yellow, and red forms, and also performed correctly during equivalence tests, ranging from 95-100% correct responses. In Phase 7 (that established and arbitrary function for each of the nonsense words), participants required between 16 and 17 trials to master the key-pressing responses in the presence of the nonsense words. Finally, during Phase 8 (contextual control), in which the blue, yellow, and red stimuli were presented within the frames, all participants scored 100% correct responses; that is, whenever the colored stimuli were presented within the Frame Physical, the participants responded based on non-arbitrary stimulus relations (i.e., the physical property of color); whenever the colored stimuli were presented within the Frame Arbitrary, participants responded based on derived arbitrary stimulus (i.e., equivalence) relations between the colored stimuli and the nonsense words.

The first part of Experiment 2 was a successful direct replication of Experiment 1’s findings. One participant needed exposure to a third cycle to demonstrate contextual control; two participants performed similarly to participants in Experiment 1. First, these results support the transfer of function as a robust phenomenon, replicated across multiple studies in different laboratories (e.g., de Rose et al. 1988; Dougher et al., 1994; Dymond & Rehfeldt, 2000; Gandarela et al., 2020; Perez et al., 2019, 2020). Second, the contextual control over the derived transfer of stimulus functions is a similarly replicable finding (e.g., Barnes et al., 1995; Dougher et al., 2002; Perez et al., 2021; Perez, Fidalgo et al., 2015; Perkins et al., 2007).

GENERAL DISCUSSION

There is a rich literature on the derived transfer of functions and the contextual control over such transfer. However, the current study (considering both experiments) is the first we know of that sought to demonstrate two types of contextual control over the transfer of stimulus functions, one based on non-arbitrary stimulus relations and the other on derived (arbitrary) relations. Analyzing these two types of contextual control in the basic research laboratory seems to be important because such shifts in contextual control in the natural environment, at least for verbally sophisticated humans, are likely very common. For example, imagine a card game in which players were asked to win cards with pictures of white animals (e.g., lab rats, rabbits, sheep, doves); in this case, the appetitive function of each card would be determined by the color of the animal. However, if players were then asked to win cards based on specific animal species such as dogs, the physical properties of the stimuli would become far less important (e.g., two cards depicting an Irish wolfhound and a chihuahua would be equally appetitive). In this latter case, the appetitive functions of the stimuli would be largely determined by the arbitrary relations between the word “dog” and the wide variety of physical forms that constitute the species “dog”.

The results of the current study provide the beginnings of a relatively precise experimental model of the two types of contextual control described above. In drawing this conclusion, it is important to recognise that Experiment 2 appears to preclude an alternative explanation for the current findings. As argued previously, the contextual control of stimulus functions observed in Experiment 1 may be interpreted as a type of compound conditional control (e.g., Meehan & Fields, 1995; Modenesi & Debert, 2015; Stromer et al., 1993). As suggested by Meehan and Fields

(1995; see also Dougher et al., 2002; Perkins et al., 2007), the demonstration of "genuine" contextual control requires that such control is generalized to novel stimulus events. Although the test for contextual control in the current study involved novel equivalence classes across Cycles 2 and 3, the results could be explained, in part, by the generalization of the contextual control due to the physical similarity between the stimuli from the multiple cycles. However, Experiment 2 demonstrated that the contextual control over function transfer, based on non-arbitrary (different types of lines) and arbitrary stimuli, *generalized* to novel stimuli in terms of their topography (words and colors) and functions (pressing numbers). In this sense, therefore, the use of the term contextual control seems fully justified in describing the current findings.

Throughout the current article, we have referred to two types of contextual control over the transfer of functions based on non-arbitrary or arbitrary stimulus relations. One interpretation of these two forms of contextual control is that the non-arbitrary relational responding simply involved primary stimulus generalization generated by *direct* histories of reinforcement; whereas the arbitrary relational control involved *indirect* derived relational learning. At a procedural level, this interpretation seems entirely reasonable because in the first case the stimulus control involved directly trained responses based on physical properties; in the latter case, the stimulus control involved relating stimuli in the absence of any obvious physical, formal similarities. At the level of behavioral process, however, it may be the case that both forms of contextual control involved a single core behavioral process. That is, given that all participants were verbally sophisticated adults, conceptually it could be argued that each of their learning histories involved many years of arbitrarily applicable relational responding (AARR; see Hayes et al., 2001). As such, those histories were likely brought to bear in both contexts and thus even when the relations were non-arbitrary, the history of *arbitrary* relational responding was still at play. For example, once an individual has learned to respond to the verbal stimulus “same”, such responding, at the level of process, is functionally similar whether responding to non-arbitrary or arbitrary stimulus properties (Hayes, Gifford, et al., 2001). In general, behavioral processes are typically defined in terms of patterns of behavioral histories and not procedures alone. Although this may be a conceptually challenging argument, it seems important to note it in the context of the current study in which non-arbitrary and arbitrary relational control was deliberately manipulated within the experiments.

As argued in the Introduction, the types of contextual control observed in the current study may also help provide increasingly precise analyses of at least some of the behavioral processes involved in behavior therapy, particularly ACT (Hayes et al., 2012). Specifically, we suggested that it may be useful to begin to interpret the ACT concept of defusion by distinguishing between the evoking versus relational properties of equivalence classes and other derived relations (see Barnes-Holmes et al., 2020 and Harte et al., 2022 for detailed accounts). The core suggestion is that precise experimental analyses of defusion (and the opposite, fusion) will involve measuring the relative dominance of Cfunc (e.g., emotional) versus Crel (e.g., semantic) stimulus properties. Recent research has suggested that it is possible to measure the relative dominance of such properties using the implicit relational assessment procedure (IRAP; see Barnes-Holmes & Harte, 2022b). The IRAP generates four separate effects by calculating differences in response latencies on trials that ask participants to confirm specific propositions (e.g., Spiders are bad – True) in one context and to disconfirm those propositions (Spiders are bad – False) in another context. Recent research has targeted the the relative differences among the four IRAP effects, in both empirical and conceptual analyses, leading to the development of the differential arbitrarily applicable relational responding effects (DAARRE) model (see Barnes-Holmes, et al., 2018).

According to the model, when the Cfunc (e.g., emotional) properties of IRAP stimuli dominate over the Crel (semantic) properties, the relative sizes of the four trial-type effects vary considerably (i.e., there is "fusion" with the emotional properties of the IRAP stimuli). In contrast, when the trial-type effects are relatively even, this indicates low levels of fusion because the stimuli in the IRAP are being related to each other based largely on their semantic properties alone. These two patterns of responding on the IRAP may thus allow for a relatively precise experimental analysis of the distinction between fusion and defusion. Interestingly, it could be argued that the current study involved manipulating contextual control over Cfunc and Crel properties, although in this case the Cfunc control did not target emotional functions. Rather, the Cfunc properties involved the formal, non-arbitrary properties of the stimuli. In making this distinction we recognise that viewing the non-arbitrary properties of the stimuli (e.g., lines and colors) might not be readily interpreted as Cfuncs, but the recent research noted above on the DAARRE model in fact drew on so-called Cfunc *orienting* properties involving shapes and colors (e.g., Finn et al., 2018). In any case, this general approach would involve developing an increasingly precise process-based account of ACT techniques rooted in the experimental analysis of contextual control over the derived transfer of functions.

Irrespective of these more abstract conceptual issues and how they might be linked to applied concerns (e.g., in the ACT literature), the current study seemingly provides a relatively precise demonstration of two types of generalized contextual control over derived function transfer. The study of derived relational responding, including transfer and contextual control, has increasingly drawn on these phenomena in analyzing complex human behavior, particularly in clinical settings. It thus seems important to continue to develop laboratory-based experimental models of the putative behavioral processes that are central to such analyses. The current study, we believe, provides one such example of this research enterprise.

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Table 1

Results from Experiment 1.

Experimental phase		Cycle	Participants			
			P1	P2	P3	P4
Phase 1	Training (# trials)	-	39	34	48	76
	Testing (% correct)	-	100	100	100	100
Phase 2	Training (# trials)	1	77	96	93	81
		2	89	81	102	89
		3	81	82	79	82
	Testing (% correct)	1	100	100	100	100
		2	100	100	100	100
		3	100	100	100	100
Phase 3	Training (# trials)	1	19	17	21	17
		2	19	16	16	16
		3	16	16	17	16
Phase 4	Testing (% correct)	Without frames*	61	0	6	100
		1	46	50	50	50
		2	94	98	100	98
		3	98	98	100	100
	Training (# trials)	1	285	42	95	42
		2	36	36	64	36

Note: *Trials to attain criterion in training and percentage of correct responses in tests across the experimental phases (Phase 1-4). Results from Phase 2-4 are presented for each cycle.* (*indicates results from Phase 4 testing without the frames considered as correct responses based on derived (arbitrary) functions).

Table 2

Experiment 2 results (Experiment 1 direct replication).

Experimental phase		Cycle	Participants		
			P5	P6	P7
Phase 1	Training (# trials)	-	38	93	77
	Testing (% correct)	-	100	100	100
Phase 2	Training (# trials)	1	100	89	92
		2	86	79	94
		3	84	82	86
	Testing (% correct)	1	100	95	95
		2	95	100	100
		3	100	100	100
Phase 3	Training (# trials)	1	33	17	22
		2	17	16	17
		3	16	16	16
Phase 4	Testing (% correct)	Without frames*	0	0	31
		1	50	50	54
		2	31	98	96
		3	100	100	100
	Training (# trials)	1	98	130	102
		2	170	36	42

Note: *Trials to attain criterion in training and percentage of correct responses in tests across the experimental phases (Phase 1-4). Results from Phase 2-4 are presented for each cycle.* (*indicates results from Phase 4 testing without the frames considered as correct responses based on derived (arbitrary) functions).

Table 3

Experiment 2 Results From Generalized Contextual Control Test.

Experimental phase		Participants		
		P5	P6	P7
Phase 5	Training (# trials)	24	30	28
	Testing (% correct)	100	100	100
Phase 6	Training (# trials)	75	81	83
	Testing (% correct)	100	100	95
Phase 7	Training (# trials)	16	16	17
Phase 8	Testing (% correct)	100	100	100

Note: *Trials to attain riterion in training and percentage of correct responses in rests across the experimental phases (Phase 5-8).*

Figure 1

Experiment 1: Stimuli and Key-Pressing Responses from Multiple Cycles of Training and Testing.

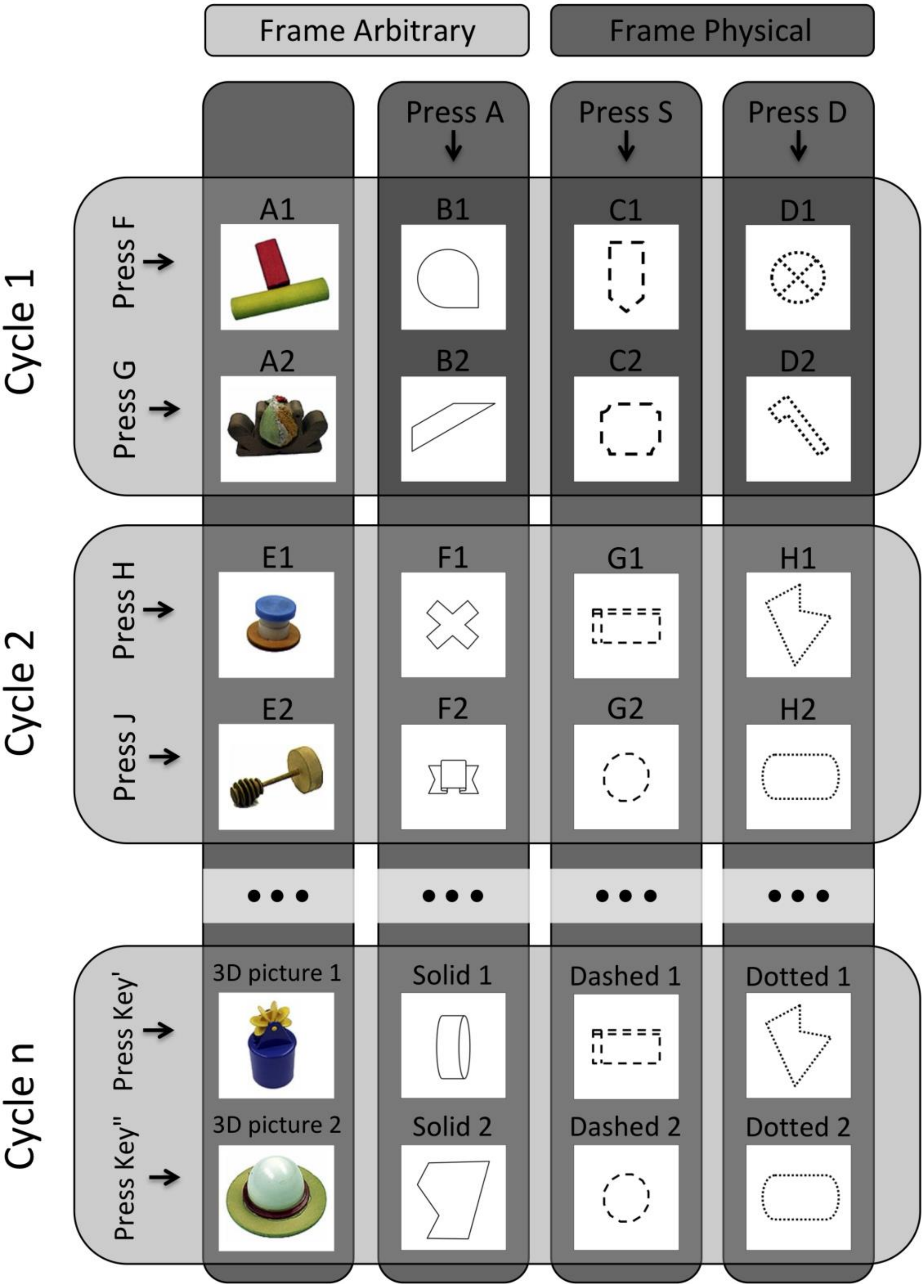
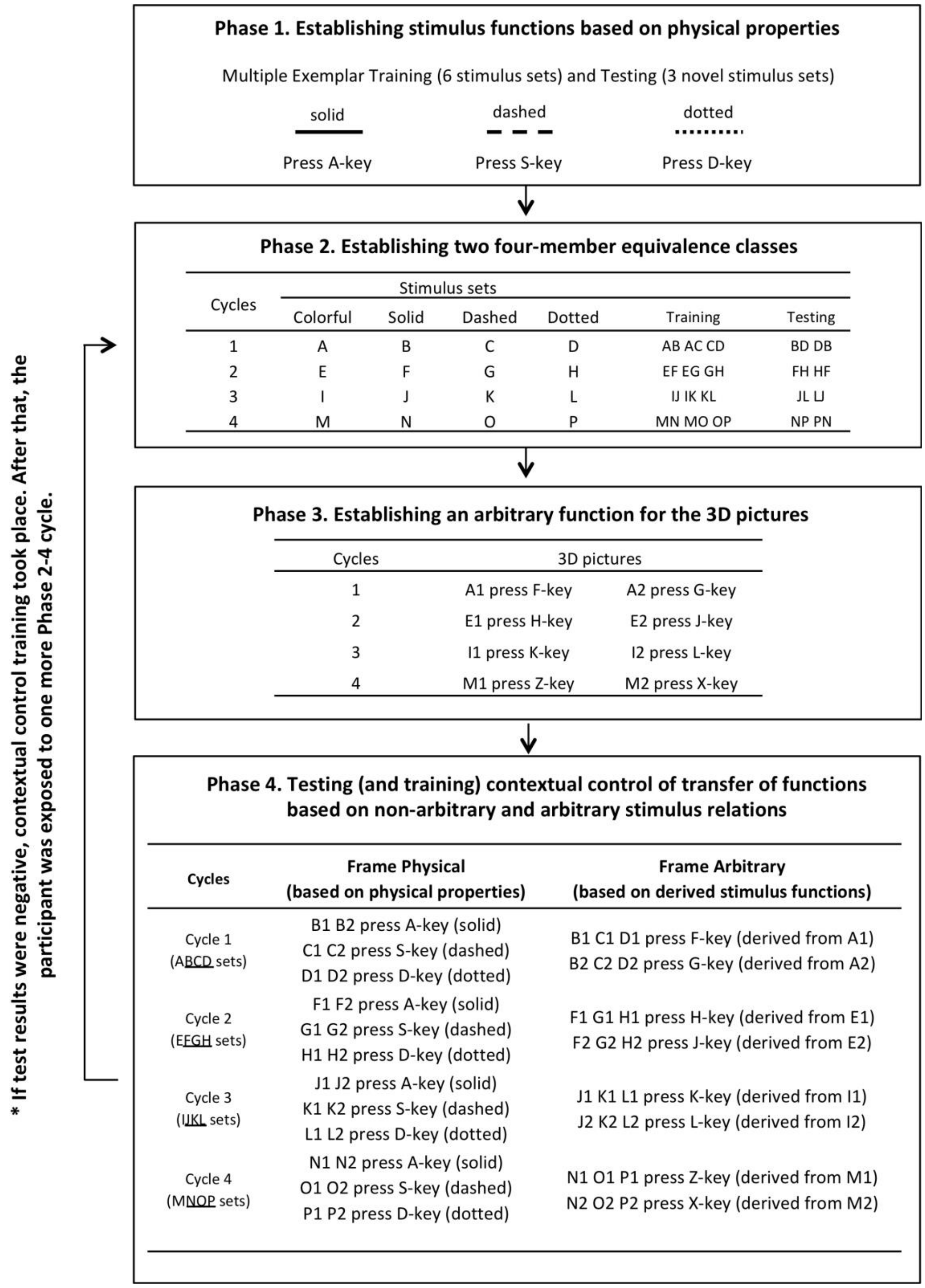


Figure 2

Experiment 1: Experimental Phases.



Phase 1. Establishing stimulus functions based on physical properties

Multiple Exemplar Training (6 stimulus sets) and Testing (3 novel stimulus sets)

solid	dashed	dotted
Press A-key	Press S-key	Press D-key

Phase 2. Establishing two four-member equivalence classes

Cycles	Stimulus sets					
	Colorful	Solid	Dashed	Dotted	Training	Testing
1	A	B	C	D	AB AC CD	BD DB
2	E	F	G	H	EF EG GH	FH HF
3	I	J	K	L	IJ IK KL	JL LJ
4	M	N	O	P	MN MO OP	NP PN

Phase 3. Establishing an arbitrary function for the 3D pictures

Cycles	3D pictures	
1	A1 press F-key	A2 press G-key
2	E1 press H-key	E2 press J-key
3	I1 press K-key	I2 press L-key
4	M1 press Z-key	M2 press X-key

Phase 4. Testing (and training) contextual control of transfer of functions based on non-arbitrary and arbitrary stimulus relations

Cycles	**Frame Physical (based on physical properties)**	**Frame Arbitrary (based on derived stimulus functions)**
Cycle 1 (ABCD sets)	B1 B2 press A-key (solid) C1 C2 press S-key (dashed) D1 D2 press D-key (dotted)	B1 C1 D1 press F-key (derived from A1) B2 C2 D2 press G-key (derived from A2)
Cycle 2 (EFGH sets)	F1 F2 press A-key (solid) G1 G2 press S-key (dashed) H1 H2 press D-key (dotted)	F1 G1 H1 press H-key (derived from E1) F2 G2 H2 press J-key (derived from E2)
Cycle 3 (IJKL sets)	J1 J2 press A-key (solid) K1 K2 press S-key (dashed) L1 L2 press D-key (dotted)	J1 K1 L1 press K-key (derived from I1) J2 K2 L2 press L-key (derived from I2)
Cycle 4 (MNOP sets)	N1 N2 press A-key (solid) O1 O2 press S-key (dashed) P1 P2 press D-key (dotted)	N1 O1 P1 press Z-key (derived from M1) N2 O2 P2 press X-key (derived from M2)

*** If test results were negative, contextual control training took place. After that, the participant was exposed to one more Phase 2-4 cycle.**

Figure 3

Experiment 2: Stimuli and Key-Pressing Responses.