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Measuring the "transfer of meaning" through members of equivalence classes merged via a class-specific reinforcement procedure

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Abstract Seven participants received conditional discrimination training that established the 12 conditional relations A1B1, A2B2, A3B3, A1C1, A2C2, A3C3, D1E1, D2E2, D3E3, D1F1, D2F2, and D3F3. The A stimuli were pictures of faces portraying emotional expressions; the others were arbitrary forms. Correct responses resulted in presentations of class-specific reinforcers, Sr1, Sr2, and Sr3. After training, tests confirmed the formation of ABC and DEF equivalence classes. Further tests then documented the merger of the classes and the emergence of SrB, SrC, SrE, and SrF relations, showing that the class-specific reinforcers were equivalence class members. Finally, participants did Semantic Differential ratings that tested whether the emotional valence of the A stimuli transferred to the arbitrary forms, B and E. The results show that participants' evaluations of the B and E stimuli were similar to evaluations of the A stimuli made by participants of a control group. This finding is considered as a demonstration that class-specific outcomes can mediate class merger phenomena and the transfer of functions through members of merged classes.

Keywords Class merger · Class-specific reinforcers · Transfer of meaning · Undergraduates

Matching-to-sample (MTS) performances are usually established by making a single type of reinforcer (e.g., a point, a type of food, a token) contingent upon selection, on each trial, of the comparison stimulus designated as correct by the experimenter. The selections are made from displays of two or more comparison stimuli. This non-specific reinforcement procedure is used to train conditional discriminations that establish relations between sample and comparison stimuli. For example, training may use points as reinforcers following selections of stimulus B1 rather than stimulus B2 in the presence of sample A1, and B2 rather than B1 in the presence of sample A2. These contingencies produce relations A1B1 and A2B2, respectively. Under some circumstances, however, participants may demonstrate additional performances that were not trained directly. To illustrate this, after training that establishes the relations A1B1, A2B2, B1C1, and B2C2, human participants are likely also to respond in accordance with symmetry by demonstrating relations B1A1, B2A2, C1B1, and C2B2, transitivity (A1C1 and A2C2), and equivalence (C1A1 and C2A2). These emergent performances allow the inference that two classes of equivalent stimuli have formed, one containing A1, B1, and C1, the other A2, B2, and C2 (Arntzen, 2012; Sidman, 1994, 2000; Sidman & Tailby, 1982). The stimuli in each class are substitutable for one another.

Following equivalence class formation, it becomes possible to demonstrate that other class members perform the stimulus functions trained to one class member without further training. This phenomenon is found for several functions of stimuli, such as simple discriminative functions (de Rose, McIlvane, Dube, Galpin, & Stoddard, 1988; de Rose,

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McIlvane, Dube, & Stoddard, 1988; Fields, Adams, Verhave & Newman, 1993; Fields, Landon-Jimenez, Buffington, & Adams, 1995), self-discriminative functions (Dymond & Barnes, 1994) ordinal properties (Mackay, Stoddard & Spencer, 1989; Wulfert & Hayes, 1988), eliciting functions (Dougher, Augustson, Markham, Greenway, & Wulfert, 1994). This outcome, often said to reflect transfer of functions, has also been shown in experiments in which pictures of facial expressions depicting emotional responses with phylogenetic relevance become equivalent to abstract stimuli (Bortoloti & de Rose, 2007, 2009, 2011; Bortoloti, Rodrigues, Cortez, Pimentel, & de Rose, 2013). In this case, the meaning of the abstract stimuli (measured by instruments such as the Semantic Differential; Osgood, Suci, & Tannenbaum, 1957) approaches the meaning of the equivalent facial expressions, which sometimes is designated as transfer of meaning (e.g., Silveira, Aggio, Cortez, Bortoloti, Rico & de Rose, 2016).

It is also possible to train conditional discriminations using class-specific reinforcers. For instance, Johnson, Meleshkevich and Dube (2014) trained typical adults with the conditional discriminations A1B1, A2B2, A3B3, A1C1, A2C2, A3C3, D1F1, D2F2, D3F3, E1F1, E2F2, and E3F3. Selections on trials that established the A1B1, A1C1, D1F1, and E1F1 relations were reinforced by Sr1. On training trials for relations A2B2, A2C2, D2F2, and E2F2 and, separately, A3B3, A3C3, D3F3, and E3F3 the reinforcers were Sr2 and Sr3, respectively. Following the acquisition of the 12 conditional discriminations, non-reinforced probe trials assessed the emergence of symmetry (relations BA, CA, FD, and FE), transitivity (BC and DF), and equivalence (CB and FD). The data showed that training gave rise to three ABC classes (A1B1C1, A2B2C2, and A3B3C3) and three DEF classes (D1E1F1, D2E2F2, and D3E3F3). Follow-up tests then assessed relations AD, DA, AE, EA, AF, FA, BD, DB, BE, EB, BF, FB, CD, DC, CE, EC, CF, FC, thus probing for merger of the classes linked by the common reinforcers. Participants' performances on these tests suggested that the ABC and DEF classes merged into the three six-member equivalence classes A1B1C1D1E1F1, A2B2C2D2E2F2, and A3B3C3D3E3F3. Additional testing also revealed that Sr1 as a sample cued selection of comparisons A1, B1, C1, D1, E1, and F1 thus confirming emergence of relations Sr1A1, Sr1B1, Sr1C1, Sr1D1, Sr1E1, and Sr1F1. Likewise tests with Sr2 and Sr3 as samples cued selection of the stimuli from Class 2 and Class 3, respectively, as comparisons. The reinforcers also functioned as comparison stimuli: The participants selected Sr1 in trials with A1, B1, C1, D1, E1, and F1 as samples. Analogous performances occurred with Sr2 and Sr3 as correct comparisons. These data showed that Sr1, Sr2, and Sr3 were included in the respective merged classes, A1B1C1D1E1F1Sr1, A2B2C2D2E2F2Sr2, and A3B3C3D3E3F3Sr3.

The study of Johnson et al. (2014), along with many others (Dube, McIlvane, Mackay, & Stoddard, 1987; Dube, McIlvane, Maguire, Mackay, & Stoddard, 1989; Dube & McIlvane, 1995; Goyos, 2000; Joseph, Overmeier, & Thompson, 1997; Minster, Jones, Ellife, & Muthukumaraswamy, 2006; Schenk, 1994; Varella & de Souza, 2014, 2015), suggested that the use of class-specific reinforcers may do more than increase the frequency of operant behavior that is under conditional stimulus control. These reinforcing stimuli may gain membership in the equivalence classes that are established and act as nodes (cf., Fields, Verhave, & Fath, 1984) that allow the classes to merge. It may be expected that, after the merger, all members of the enlarged class may perform functions (e.g., discriminative, eliciting) trained to only one of the members in each class. However, this prediction has not yet been verified. The purpose of this research was to verify this potential outcome. Moreover, since the prospective classes included faces portraying emotions, a comparison of the ratings of faces and abstract stimuli equivalent to them would yield a quantitative estimation of transfer of functions.

To achieve these novel research goals, the procedure of Johnson et al. (2014) was modified to include sets of pictures of human faces expressing emotions that were made equivalent to arbitrary forms as in the experiments of Bortoloti and de Rose (2011). To enhance the salience of the differential consequences within the training contingencies, participants were required to emit a consummatory response following the presentation of each class-specific reinforcer.

Seven participants received MTS training to establish AB, AC, DE, and DF relations using the class-specific reinforcers Sr1, Sr2, and Sr3. Stimuli from set A (A1, A2, and A3) were pictures of human faces with emotional expressions (happiness, neutrality and anger). All the remaining stimuli (B1, B2, B3, C1, C2, C3, D1, D2, D3, E1, E2, E3, F1, F2, and F3) were arbitrary forms. This training was intended to establish "meaningful" classes with the faces as members (ABC classes) and classes of arbitrary forms (DEF classes). After demonstration of these classes, participants were given tests for relations BE, EB, BF, FB, CE, EC, CF, FC and SrB, SrC, SrD, SrE, SrF to verify class merger and inclusion of the reinforcing stimuli into these classes (i.e., ABCDEFSr classes). These data would provide a systematic replication of Johnson et al. (2014). At the last step of this research, the Semantic Differential ratings provided a quantitative estimation of transfer of "meaning" between class members related solely by a common reinforcer.

Method

Participants

Participants were 17 undergraduate students at a Brazilian university, whose ages ranged from 18 to 24 years. All instructions were given in Brazilian Portuguese. Ten participants were assigned to the Control Group and seven to the Experimental

Group. Participants from the Experimental Group watched an instructional video before exposure to the MTS procedures.

Setting, equipment, and stimuli

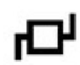
The experimental procedures were conducted in a small laboratory room using a Macintosh MAC OS. The software, Gerenciador de Ensino Individualizado por Computadorizado – GEIC (Computerized Manager for Individualized Teaching), developed by Capobianco, Teixeira, Bela, Orlando, de Souza, and de Rose (2009), presented the visual and auditory stimuli and accumulated points earned by participants. Participants' selections were recorded automatically.

Table 1 shows the stimuli used in this experiment. Those labeled A1, A2, and A3 were 12 pictures of human faces that comprised three sets of four, expressing the emotions happiness, neutrality, and anger, respectively. These pictures were obtained from the CD-ROM "Pictures of Facial Affect," purchased from Paul Ekman's website (www.paulekman.com). The arbitrary forms that served as stimuli for sets B, C, D, E, and F were available on the Mac OS. Gray and white copies of the stimuli were made for use as incorrect comparisons in the earliest stages of the training that established baseline conditional discriminations.

Class-specific reinforcers The three class-specific reinforcers, Sr1, Sr2, and Sr3, were distinct combinations of an auditory stimulus (Sound 1, Sound 2, and Sound 3) and a distinctive logo representing a store located on the university campus. The logos (shown at bottom in Table 1) represented an office supplies store (Fast Copy – Logo 1), a cafeteria (PQ – Logo 2), and a bookstore (EDUFSCar – Logo 3).

Semantic differentials Figure 1 illustrates the paper sheets prepared for use in the Semantic Differential ratings performed by participants in the Experimental and Control

Table 1 Stimuli used in the experiment

	Class 1	Class 2	Class 3
A			
B			
C			
D			
E			
F			
Logos (Specific reinforcers)	FAST COPY	PQ	EdUFSCar

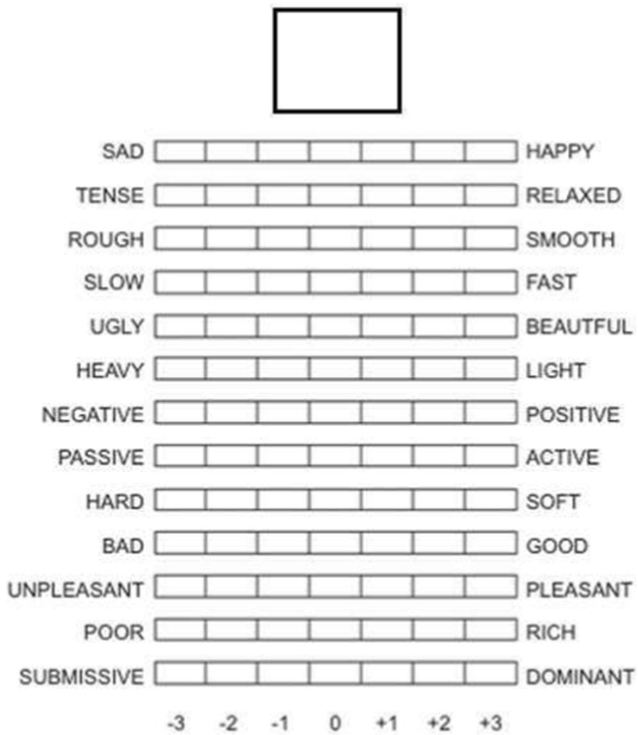


Fig. 1 A representation of the 13 scales of the Semantic Differentials. By convention, the stimuli are always presented at the top of the sheet of paper, as exemplified by the blank square. The left-right positions of the adjectives were counterbalanced. The values -3, -2, -1, 0, +1, +2 and +3 were not available for the participants

groups. The stimulus to be evaluated was printed at the top of the sheet and 13 scales were positioned below it. Each scale, which comprised seven values, was anchored by two opposite adjectives, and represented steps in a continuum that ranged from one adjective to its opposite. The Semantic Differential as used in this study was validated by a psychometric study reported by Almeida, Bortoloti, Ferreira, Schelini, and de Rose (2014).

Procedure

General overview

Pre-training Before training began, all participants watched a video that provided instructions for the MTS task and demonstrated the consummatory response requirement to collect points earned (cf., Costa, Patsko & Becker, 2007; Matthews, Shimoff, Catania & Sagvolden, 1977). This video, which can be accessed via https://www.researchgate.net/publication/282133851_Instruc_Video?ev=prf_pub, was introduced with the statement, “Pay close attention to the video because it will instruct you how to perform the task and how to accumulate points.” After watching the video, all participants read printed instructions, describing how points could be earned and exchanged via gift cards at on-campus stores identified by their logos (Appendix 1). Then each participant wrote in the blank spaces located below the logos, the monetary value to be given at the respective stores for each point earned (in Brazilian currency R$0,05, R$0,07, and R$0,10). Therefore, the monetary value of points varied for each store, according to the participants’ assignment at this time. The experimenter asked whether participants understood that points would be converted to gift cards to be used for shopping in an office supplies store, a cafeteria, or a bookstore. The procedure was called the Personal Credit System (Appendix 1).

MTS trials MTS procedures were used for baseline training and tests. All trials began with presentation of a sample stimulus centered in the upper part of the computer screen. A mouse click to the sample resulted in presentation of a row of three comparison stimuli on the lower portion of the screen. The same sample and configuration of comparisons never appeared on more than two consecutive trials. The comparison stimuli appeared in each possible location in an equal number of times. Participants selected a comparison stimulus with a mouse click. The selections designated as correct by the experimenter resulted in the removal of all stimuli from the computer screen and the presentation of “Sound 1,” “Sound 2,” or “Sound 3” depending on the stimuli presented. Sound 1 was contingent upon selections of stimuli from Class 1, Sound 2 on correct trials involving stimuli from Class 2, and Sound 3 on correct trials involving stimuli from Class 3. The sound lasted 1.5 s. After termination of the sound, the class-consistent logo appeared in the lower portion of the screen and remained present until the participant made a mouse click above the logo as a consummatory response that provided access to one point. Here the mouse click caused replaying of the auditory stimulus and the addition of one point to a counter positioned above the logo. The logo then was removed and a new trial began. Incorrect selections resulted only in the removal of all stimuli from the computer screen. The next trial began immediately.

Baseline training These procedures were used for training the AB, AC, DE, and DF baseline conditional relations (see Table 2). These baseline relations were trained in two blocks of trials. The first block comprised 12 trials of simultaneous MTS (SMTS). On these trials, a click on the sample produced the comparison stimuli immediately. The sample and comparisons then remained on the screen until the participant selected a comparison. During SMTS training, the sample stimulus and the correct comparison were black and white while the incorrect comparisons were the gray copies. When the A stimuli served as samples each of the four faces with the same emotional expression appeared equally often in unsystematic order. Perfect performance was required to progress to a block

Table 2 Sequence of training and test phases

Steps	Phases Relations	Trained or Tested
1) Establishment of ABC Class	AB Training	A1B1, A2B2 and A3B3
	AC Training	A1C1, A2C2 and A3C3
	Cumulative Baseline 1	A1B1, A2B, A3B3, A1C1, A2C2 and A3C3
	BC Test	B1C1, B2C2 and B3C3
	CB Test	C1B1, C2B2 and C3B3
2) Establishment of DEF Class	DE Training	D1E1, D2E2 and D3E3
	DF Training	D1F1, D2F2 and D3F3
	Cumulative Baseline 2	D1E1, D2E2, D3E3, D1F1, D2F2 and D3F3
	EF Test	E1F1, E2F2 and E3F3
	FE Test	F1E1. F2E2 and F3E3
3) Class Merger Tests	Cumulative Baseline 3	D1E1, D2E2, D3E3, D1F1, D2F2 and D3F3
	BE Test	B1E1, B2E2 and B3E3
	EB Test	E1B1, E2B2 and E3B3
	FB Test	F1B1, F2B2 and F3B3
	BF Test	B1F1, B2F2 and F3B3
	Cumulative Baseline 4	A1B1, A2B, A3B3, A1C1, A2C2, A3C3, D1E1, D2E2, D3E3, D1F1, D2F2 and D3F3
	CE Test	C1E1, C2E2 and C3E3
	EC Test	E1C1, E2C2 and E3C3
	CF Test	C1F1, C2F2 and C3F3
	FC Test	F1C1, F2C2 and F3C3
4) Reinforcers Class Membership	Reinforcer-as-sample Test	Sr1B1, Sr1C1, Sr1E1, Sr1F1, Sr2B2, Sr2C2, Sr2E2, Sr2F2, Sr3B3, Sr3C3, Sr3E3 and Sr3F3

of 36 trials with a zero-delay MTS (DMTS) procedure. On these trials, a click on the sample removed it and immediately produced the black comparison stimuli. The criterion for the DMTS blocks was 85 % correct trials.

To simplify presentation of the remaining procedures, from now on comparison selections consistent with the class membership of the current sample will be referred as "correct." Selections inconsistent with the class membership of the current sample will be referred to as "incorrect."

Cumulative baselines The purpose of the Cumulative Baseline was to expose participants to a mixture of all current baseline trial types before probes for emergent performances and effects of class merger were given. All blocks contained 48 trials. For Cumulative Baseline 1, stimuli from set A were samples and stimuli from sets B and C were comparisons (Table 2). This block contained a mixture of 24 AB and 24 AC baseline trials. For Cumulative Baseline 2, stimuli from set D were samples and stimuli from sets E and F were comparisons. This block contained 24 DE and 24 DF intermixed trials. Cumulative Baselines 3 and 4 were identical and involved mixtures of these four trial types: 12 AB, 12 AC, 12 DE, and 12 DF trials. For all Cumulative Baselines the presentation of the trials was counterbalanced in such a way that each trial type could not be presented on more than two consecutive trials. Accuracy criterion for Cumulative Baseline 1 and Cumulative Baseline 2 was 97 %. Perfect accuracy was required for Cumulative Baselines 3 and 4.

Equivalence tests The emergence of relations B1C1, B2C2, B3C3, C1B1, C2B2, and C3B3 was verified in two blocks of trials that followed demonstration of criterion performance in Cumulative Baseline 1 (Table 2). The BC tests were conducted in a single 24-trial block in which the stimuli B1, B2, and B3 each appeared eight times as sample and C1, C2, and C3 were presented as comparisons. CB testing then followed using the same procedure. To confirm formation of ABC classes, 95 % correct trials were required within each block.

Tests for the emergence of relations E1F1, E2F2, E3F3, F1E1, F2E2, and F3E3 were given in the same manner, following completion of Cumulative Baseline 2. The EF tests comprised a single 24-trial block in which the stimuli E1, E2, and E3 occurred eight times as sample and stimuli F1, F2, and F3 were presented as comparisons. The FE tests then were conducted using the same procedure. The criterion used to confirm the formation of DEF classes was the same as for the ABC classes.

Class merger tests Following the completion of Cumulative Baseline 3, participants were given BE (B1E1, B2E2 and B3E3), BF (B1F1, B2F2 and B3F3), EB (E1B1, E2B2 and E3B3), and FB (F1B1, F2B2 and F3B3) class-merger tests (Table 2). The accuracy criterion was 91 % correct trials in at least six of these test blocks to progress to Cumulative Baseline 4, and then to blocks of CE (C1E1, C2E2 and C3E3), CF (C1F1, C2F2 and C3F3), EC (E1C1, E2C2 and E3C3) and FC (F1C1, F2C2 and F3C3) class merger tests (Table 1). Each block comprised 24 trials as on the equivalence tests.

Reinforcer-as-sample test These tests examined whether the class-specific reinforcers were members of the equivalence classes (Table 2). The tests comprised one block with 48 trials of DMTS (Table 1). Each trial began with the presentation of a logo and a sound as a compound sample (Logo 1 + Sound 1, Logo 2 + Sound 2 or Logo 3 + Sound 3). Each of these combinations was presented as the sample on 16 trials. The arbitrary stimuli from sets B, C, E, and F were presented as comparisons on 12 trials. The same sample stimulus could not occur on more than three consecutive trials and the same comparison stimuli could not be presented on more than two consecutive trials. The criterion of 80 % correct trials was required before participants had to complete the Semantic Differential evaluation.

Semantic differential

Experimental group Participants who attained criterion on the earlier phases evaluated stimuli B1, B2, B3, E1, E2, and E3 with the Semantic Differential (Fig. 1). Written instructions were presented to the participants (Appendix 2).

Control group Participants in this group only evaluated stimuli from set A (faces) using the Semantic Differential. They met in the same classroom and completed the instrument individually. They were given the same written instructions as participants from the Experimental group but were not exposed to training and testing.

Results

Establishing ABC and DEF equivalence classes

All participants achieved the learning criterion for the AB, AC, DE, and DF training and the Cumulative Baselines 1 and 2. All then performed perfectly on the BC, CB, and EF tests for equivalence. On the FE tests, only P5 showed less than perfect performance (95 % correct). Participants' percentages of correct responding for the training and test phases are shown at https://www.researchgate.net/publication/275041069_Individual_data_from_participants_of_Maintenance_of_Equivalence_Classes_and_Transfer_of_Functions.

Tests for class merger and reinforcer membership

Table 3 shows participants' performances on the phases of the experiment that followed establishment of the ABC and DEF classes. In Cumulative Baseline 3, participants P2, P3, and P4 required more than one block to meet the accuracy criterion. Then, all but participant P5 scored at least 90 % correct on the BE, BF, EB, and FB tests. For Cumulative Baseline 4, only participant P2 needed two blocks to meet criterion. Subsequently, most participants scored better than 90 % correct on the CE, CF, EC, and FC tests and thus demonstrated the expected class mergers. The only exception was P5 who scored 58 % on the CE tests but above criterion on the others. Finally, all participants met criterion on the Reinforcer-as-Sample Test block, confirming that Sr1, Sr2, and Sr3, had become members of their respective equivalence classes.

Semantic differential evaluations of B and E stimuli Figure 2 summarizes the evaluations of the B and E arbitrary stimuli made by the seven participants in the Experimental Group, and the evaluations of A stimuli

Table 3 Percentage correct trials achieved by participants on Cumulative Baseline 3 and 4, on tests BE, BF, EB, EF, CE, CF, EC, CF and Reinforcer-as-Sample tests

Phases	Criterion	Participants						
		P1	P2	P3	P4	P5	P6	P7
Cumulative Baseline 3	100	100	98 98 100	100	98100	98 98 100	100	100
BE Tests	91	100	100	91	100	98	91	91
BF Tests	91	100	100	100	100	100	100	91
EB Tests	91	95	100	100	91	58	100	100
FB Tests	91	100	95	100	95	91	100	100
Cumulative Baseline 4	100	100	98 100	100	100	100	100	100
CE Tests	91	100	100	100	100	58	100	100
CF Tests	91	91	95	100	100	91	100	100
EC Tests	91	100	100	95	100	95	100	100
FC Tests	91	100	100	100	100	95	100	100
Reinforcer-as-sample Tests	80	100	100	93	98	80	98	98

(faces) made by the ten participants in the Control Group. Each data point shows the median value of the evaluations given for each scale. To facilitate presentation of these data, the stimuli related to happy, neutral, and angry faces are referred to as the Happy Class, Neutral Class, and Angry Class, respectively. The seven-level scale used in the evaluation involving each adjective pair is shown with 0 in the center, values for adjectives rated as positive to the right (+1, +2, +3) and values for adjectives rated as negative to the left (-1, -2, -3). These numbers were not printed on the evaluation sheets of paper given to the participants. The left-right positions of the adjectives were randomized.

The medians of the evaluations of Happy Class stimuli are presented at the left in Fig. 2. At the center and right are the medians of the evaluations of Neutral Class and Angry Class stimuli, respectively. The scales are listed so as to separate the Factor 1 scales (above the dotted line) from the Factor 2 scales (below the dotted line). Almeida et al. (2014) found that Factor 1 scales provided reliable assessment of the affective valence of stimuli (Cronbach's coefficient alpha, 0,91), thus providing data relevant to the aims of the present research. The Factor 2 scales were marginally reliable as measures of potency/activity (Cronbach's coefficient alpha, 0,62) and may be conceived as distractors, since the present study is concerned with valence.

Figure 2 shows that the Factor 1 evaluations for the A stimuli by the Control Group (continuous black lines with squares) were between 0 and +3 for A1 (happy faces), between -3 and 0 for A2 (angry faces), and between -1 and +1 for A3 (neutral faces). Thus, A1's affective valence is viewed as positive, A2's affective valence as negative, and A3's affective valence as neutral. For the Experimental Group, the median Factor 1 evaluations of the arbitrary stimuli, B (+) and E (o), were as follows: between 0 and +3 for B1 and E1, between -3 and 0 for B2 and E2, and between -1 and +1 for B3 and E3. Thus, the affective valence of the arbitrary form stimuli was positive, negative, and neutral for stimuli in the Happy Class, Angry Class, and Neutral Class, respectively. As expected, these class-consistent agreements between the evaluations of the A, B, and E stimuli confirmed that arbitrary forms acquire the emotional meanings of facial expressions to which they have been made equivalent via MTS training with class-specific reinforcers.

In this respect, it is important to recall that different aspects of the procedure underlie the acquisition of the emotional meanings of the B and E forms, respectively. These differences could affect the degree to which the forms came to possess the valence of the A stimuli to which they were related. The B stimuli acquired the emotional meanings of the face stimuli (A) because they were explicitly related to each other during the AB training with the class-specific reinforcers. The meanings acquired by the E stimuli, however, were established more indirectly via use of the same class-specific reinforcer for training the prerequisite conditional discriminations for the ABC and DEF classes. For

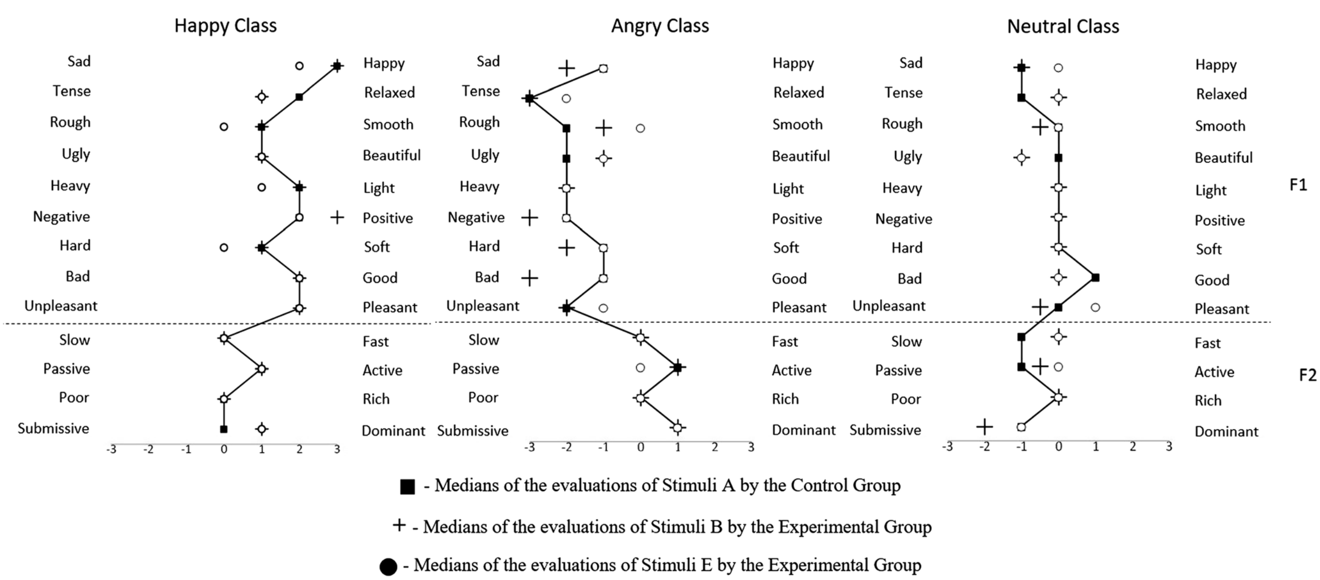


Fig. 2 Median evaluations for stimuli As, Bs and Es by the Control and Experimental Groups

example, the reinforcer Sr1 followed correct trials involving the A1B1 relation and also the D1E1 relation. This common feature resulted in merger of the two classes and therefore acquisition of the emotional meaning of A1 by E1. The different meanings of E2 and E3 were based on analogous histories.

Figure 2 shows the quantitative differences in Semantic Differential ratings that may reflect these variables. For the Happy Class, the median values for B1 evaluations overlapped the median values for A1 evaluations in seven of the nine Factor 1 scales (sad/happy; rough/smooth; ugly/beautiful; heavy/light; hard/soft; bad/good; pleasant/unpleasant). These values differed only for the tense/relaxed and negative/positive scales. However, with respect to the E stimuli, ratings for five scales (sad/happy; tense/relaxed; rough/smooth; heavy/light; hard/soft) were closer to the 0 level than the related B1 ratings, perhaps reflecting the more indirect relation between the E and A stimuli than the B and A stimuli.

The analogous comparisons within the Angry Class follow a different pattern. The median B2 evaluations overlapped the median A2 evaluations in only three of the nine Factor 1 scales (tense/relaxed, heavy/light, and unpleasant/pleasant). For two scales (rough/smooth and ugly/beautiful), the median B2 evaluations were closer to the 0 level than the related A2 evaluations. Overall, these five evaluations resemble evaluations of the A and B stimuli in the Happy class. However, in four scales (sad/happy, negative/positive, hard/soft, and bad/good), participants in the Experimental Group "over-rated" (cf., Silveira et al. 2016) B2 in comparison to the control participants' A2 evaluations for the same scales. The stimulus control of these evaluations thus differed across the contexts supplied by the form B2 on one hand and the four faces on the other, even although these stimuli were linked directly by training. Further, the median Factor 1 E2 evaluations differed from the B2 evaluations in seven of the nine scales, being closer to the 0 level in each instance. These evaluations overlapped the median A2 evaluations in five of the nine Factor 1 scales (sad/happy; heavy/light; negative/positive; hard/smooth; and bad/good). For the other four scales, the median evaluations were closer to or at the 0 level in comparison to the analogous face evaluations performed by the Control participants. For the Neutral classes, the median evaluations fell in the narrow band between the -1 and +1 levels: the arbitrary stimuli B3 and E3 overlapped the median values for A3 in three of the nine Factor 1 scales (heavy/light; negative/positive, and hard/soft).

For the remaining scales the median evaluations of B3 and E3 differed little from the median values of A3.

Discussion

The current research systematically replicated and extended the original findings of Johnson et al. (2014) by using a One-to-Many (OTM) training design with pictures of faces expressing emotions and arbitrary forms as stimuli. The aim was to examine whether arbitrary stimuli made equivalent to particular emotional expressions via this kind of baseline training would acquire the meanings or valence of the expressions, as assessed in a semantic differential. Semantic differential ratings confirmed this transfer of meaning, even for stimuli related to the faces only via the common consequences used in separate training steps.

We applied the class-specific reinforcers Sr1, Sr2, and Sr3 in training young adults to perform conditional discriminations that established AB (A1B1, A2B2, and A3B3), AC (A1C1, A2C2, and A3C3), DE (D1E1, D2E2, and D3E3), and DF (D1F1, D2F2, and D3F3) conditional relations among the stimuli. Following the training, all participants were given combined tests for emergence of symmetry and transitivity (cf., Sidman & Tailby, 1982). The scores attained by seven participants in these tests for relations BC, CB, EF, and FE first confirmed the establishment of equivalence classes ABC and DEF. Then, participants were given BE, EB, BF, FB, CE, EC, CF, and FC tests that documented the existence of these additional derived relations between members of the classes. Finally, the Reinforcer-as-Sample tests confirmed the emergence of SrB, SrC, SrE, and SrF relations. Based on these results, we inferred that three seven-member merged classes were established experimentally: A1B1C1D1E1F1Sr1, A2B2C2D2E2F2Sr2, and A3B3C3D3E3F3Sr3.

As in previous research (e.g., Bortoloti & de Rose, 2007, 2009; Lazar, Davis-Lang & Sanchez, 1984; Ribeiro, Silveira, Mackay, & de Rose, 2016; Silveira et al., 2016), tests for symmetry (e.g., BA, CA, ED, FE, ASr, BSr, and CSr) were not used at several points following baseline training in the current research in order to reduce the extent of testing. However, the accuracy of performance on trials that test for the emergence of transitive relations (BC, CB, EF, and FE), class-merger (BE, EB, BF, FB, CE, EC, FE, and FE) and Reinforcer-as-Sample (SrA, SrB, and SrC) can be considered as a reliable index of the formation of equivalence classes.

At present, it seems plausible to speculate that the use of class-specific reinforcers in training designed to establish the behavioral prerequisites for equivalence may favor occurrence of high yields of stimulus class formation and extensive transfer of the properties and functions of these stimuli across additional (derived) class members. However, future experiments are necessary for a better understanding of some variables at work. For example, detailed instructions and a video were employed with the verbally sophisticated undergraduates who participated in the present research. The aim of these procedures was threefold: modeling the topography of responses to sample and comparison stimuli, modeling the consummatory responses that collected points, and ensuring that the programmed consequences would act as specific reinforcers by requiring participants to choose the values of the points. The written instructions may be likely to induce instances of rule-following behaviors that affect participants' performances under the experimental contingencies used (cf., Arntzen, Vaidya & Halstadtro, 2008; Cortez & dos Reis, 2008; de Rose, 1996; Levin & Hamermesh, 1967; Martinez & Tamayo, 2005; Saunders, Saunders, Williams & Spradlin, 1993). However, a strong role may be seen for the contingencies themselves because the participants received no further instructions during their exposure to the blocks of training trials. In addition, the transitivity (BC, CB, EF, and FE), class-merger (BE, EB, BF, FB, CE, EC, FE, and FE) and Reinforcer-as-Sample (SrA, SrB, and SrC) tests were presented without further instructions immediately after achieving the training criteria. Follow-up studies should aim to examine effects of manipulating written instructions that precede MTS training. For example, research is needed to clarify the extent to which a set of instructions that specifies the molar features of contingencies of reinforcement might affect participants' sensitivity to the molecular features of the MTS procedure involving specific reinforcers (cf., Drake & Wilson, 2008). Would yields of stimulus class formation differ from those in the current research? In parallel, studies that modify the types of instructions for use with individuals with minimal verbal repertoires (e.g., kindergarteners; people with autism) will expand our current understanding of the relations between equivalence-like behaviors and rule-governed behaviors (cf., Sidman, 1992). The effects of video modeling upon the rate of learning arbitrary matching performances are yet unknown.

Overall, the MTS performances of participants in the Experimental Group suggest that the auditory-visual complex stimuli defined as "class-specific reinforcers" had the expected effects upon all participants' behavior even though the final steps for converting points to money lacked differential class-specific relations (i.e., points were converted to money as each individual participant had chosen before the training began). The computerized system established powerful class-specific reinforcers for young adults (cf., Galizio & Buskist, 1988; Kangas & Hackenberg, 2009) within a single session. Future experiments addressing complex learning with this population thus should benefit from use of this procedure. It may be noted that tests were not given to evaluate whether the familiar logos and novel sounds functioned separately as reinforcing stimuli and as individual members of the equivalence classes established. However, such tests could be added readily to the protocol and might clarify the role played by each of these stimuli, thus extending the work of Varela and de Souza (2014, 2015) and Monteiro and Barros (2016), who used compound stimuli as reinforcers for children with autism.

Ultimately, clinical relevance of the phenomenon is indicated by the positive effects of using class-specific reinforcers reported by Joseph et al. (1997) in research with individuals with Prader-Willi's Syndrome. These participants made more class-consistent responses on tests for the emergence of two- and three-node transitive relations following MTS training with class-specific reinforcers, than on analogous tests following MTS training with nondifferential reinforcers.

Transfer of meaning

The original contribution of this study was the demonstration of transfer of function effects across stimuli related only via class-specific consequences used to establish baseline performances. Because the Semantic Differential is highly regarded as a sensitive measure of meaning (Osgood et al., 1957), these results may be described more generally as "transfer of meaning," as done by Bortoloti and de Rose (2007, 2009, 2011). Transfer of functions is a robust phenomenon but it may not be a necessary implication of stimulus equivalence. For instance, Bortoloti and de Rose (2009; see also Fields et al., 1995) showed that transfer of meaning depends on the number of nodes in the relation between arbitrary stimuli and the faces. Transfer was demonstrated when arbitrary and face stimuli were separated by one node but was much weaker when stimuli were separated by three nodes. If number of nodes can interfere with transfer, it is conceivable that the nature of nodes might also do so. The question addressed here, then, concerned whether transfer of the meaning of the faces would also occur to stimuli related to the faces only via a class-specific consequence used in baseline training.

With respect to the stimulus control exercised by the arbitrary forms during the Semantic Differential tests, the

Experimental Group's ratings of stimuli B and E were in accord with their expected class memberships. For example, the evaluations of B1 and E1 were positive, like the evaluations of A1 stimuli (happy faces) made by the Control Group. This suggests that the forms made equivalent to these faces acquired the "emotional meanings" of the happy faces. Analogous "transfer of meaning" was observed among members of the angry class: The evaluations of B2 and E2, stimuli equivalent to A2 (angry faces), were negative. Such emergent stimulus control over the ratings of the forms is not well described in terms of reflexivity, symmetry, and transitivity, the standard requirements for equivalence (Sidman & Tailby, 1982). Rather, it is an additional result of the training that establishes the prerequisites of equivalence and may be included among factors considered by Pilgrim (2016) as potential reasons to broaden the definition of equivalence (e.g., use of class-specific reinforcers, compound conditional or discriminative stimuli, simple discrimination training).

It is important here to emphasize that in the current research, the Semantic Differentials were sensitive to the effects on the nodal structure of equivalence classes that derive from training with class-specific reinforcers. These effects differ from those produced by training that uses the same reinforcer in all training steps and have implications with respect to application of the Semantic Differential to evaluate the "transfer of meaning" of pictures of facial expressions to arbitrary stimuli. Bortoloti and de Rose (2009) used the same reinforcer in training that established three seven-member equivalence classes (A1B1C1D1E1F1G1, A2B2C2D2E2F2G2, and A3B3C3D3E3F3G3) in participants of an Experimental Group. The A stimuli were photographs with different facial expressions and the others were arbitrary forms as in the current study. Subsequently, the participants rated the abstract forms D and F in accordance with the class membership they shared with the exemplars of each facial expression. Further, Bortoloti and de Rose (2009) described a decrement in the "transfer of meaning" that was a function of the number of nodes that separated the arbitrary forms D and F from the meaningful A stimuli. The "transfer of meaning" was said to be stronger to set D forms, which were separated by one node (B) from A stimuli. In contrast, the "transfer of meaning" was said to be weaker to F forms, which were separated by three nodes (B, C, and E) from A stimuli. Based on these data, Bortoloti and de Rose (2009) stated that some arbitrary form stimuli were "more equivalent" or "more related" than other members of the same class if separated by fewer nodes. In contrast, the arbitrary forms tend to be "less related" or "less equivalent" to one another as nodal number increases. Notably, Bortoloti and de Rose (2009, 2011) recognized this view of equivalence as involving a "contradiction in terms" (cf., Sidman, 1994) and discussed other potential sources of differential stimulus control by the forms (e.g., membership of these stimuli in other additional classes). As emphasized by Sidman (1994), Bortoloti and de Rose (2009), and Doran and Fields (2012), the members of an equivalence class may also belong to other classes that derive from a particular conditional discrimination training history. For example, these stimuli may also participate in classes based on features of the stimuli such as form and color, their functions as sample and comparison stimuli (see Sidman, 1994, pp. 537-549, for discussion) or nodal number, as discussed above. However, the current results are compatible with another account: A class-specific reinforcer may serve as a single node linking all the members of one or more equivalence classes formed via these contingencies (cf., Dube et al., 1987, 1989; Dube & McIlvane, 1995; Johnson et al., 2014; Joseph et al., 1997). On that basis, of course, the effects of nodal number as described by Bortoloti and de Rose (2009) would not be expected.

Ultimately, in the present research with class-specific reinforcers, the evaluations of the form stimuli by the Experimental participants were generally consistent with the evaluations of the faces by the Control Group with some median values even overlapping, just as in Bortoloti and de Rose's research. Nevertheless, as described earlier, quantitative differences in the evaluations of B and E stimuli have occurred probably due to the more indirect relation between the E and A stimuli than between the B and A stimuli. Similar differences in the evaluations of the forms could also be seen in Bortoloti and de Rose (2009) and other experiments where training involved a common reinforcer. Differential stimulus control exercised by the B and E stimuli in the current research therefore must derive from another aspect of the experimental arrangements. The conditional discriminations involving the E stimuli were trained later than the B discriminations, and thus such differences in the Semantic Differential evaluations may have reflected the addition of E stimuli during later steps of training. We suggest that the order in which the stimuli were introduced in training may be important in that respect (cf. Stikeleather & Sidman, 1990).

In addition, it is clear that the logos and faces, each of them meaningful stimuli for the participants, had different effects in the complex relational discriminations and transfer of stimulus control examined here. These stimuli shared membership in the same equivalence classes, (e.g., face A1 with the logo in Sr1 in Class 1; face A2 with the logo in Sr2 in Class 2). Nevertheless, the face stimuli were the primary determinants of the differential stimulus control exercised by the related arbitrary forms in the Semantic Differential evaluations, a result particularly evident in the case of angry faces. The four faces in each set of A stimuli were already generalized equivalence classes (cf., Belanich & Fields, 2003) when the experiment began. Thus, their number within each class as well as their functions as samples during initial training may be factors promoting their influence. In contrast, the logos functioned as reinforcing stimuli during training, each following all correct selections of related class members. Additional research, including Semantic Differential evaluations of the reinforcing stimuli, is needed to elucidate how such factors may be involved in generating performances like those described here. If stimuli used in matching to sample were all abstract and training used specific consequences with differentiated meanings, as assessed by the Semantic Differential (for instance, a logo of a bookstore vs. a logo of a pub; or a stimulus signaling gain of points vs. a stimulus signaling avoidance of point loss), we would expect that these consequences would gain membership in the equivalence classes. Following this demonstration of transfer of meaning across stimuli related only by specific consequences, it remains for future research, to show whether the meaning of the consequences themselves may transfer to equivalent abstract stimuli. This issue requires further investigation.

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Compliance with ethical standards

Conflicts of interests All authors declare that they have no potential conflicts of interests.

Appendix 1

Personal credit system

You will be submitted to a task comprised by several trials. In each trial you must select a picture. Every time you choose a correct one you will earn a point. It is worth to earn as much points as possible because these points will be converted in gift cards with specific values, to be used for shopping on three stores located inside the campus "Fast Copy", "PQ" e "EDUFSCar".

Points will be earned every time you click on "Fast Copy", "PQ" or "EDUFSCar" logotypes. You will learn to which of these logotypes you must click. Points will be accumulated in a window located above each one of the logotypes.

Your task now is to specify the monetary values that points earned for each one of these stores, represented by its logotypes. Now, you have three values options: R$0,05; R$0,07 e R$0,10. So if, for example, you want that your points for "PQ" to be of greater value than points for "Fast Copy" and for "EDUFSCar", then you must assign R$ 0,10 for "PQ", R$ 0,07 for "Fast Copy", and R$ 0,05 for EDUSCar.

Now you are ready. Remember that the values will depend on your own decision, based on your preferences. Please, let the experimenter know as soon as you finished your personal credit system.

FAST COPY PQ EdUFSCar

____________ ____________ ____________

(*Values can be assigned only once)

Appendix 2

Instructions for the participants translated from Brazilian Portuguese into English

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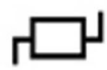
INSTRUCTIONS

You will find a picture on the top of each of the following sheets. Your task is to mark with an X the location of the picture in scales limited to opposite adjectives. Each scale represents a continuum from one adjective to its opposite. Thus, you will find, for example, the pair *beautiful/ugly* and will have to judge, based on this pair of adjectives, a figure like:



If you consider the figure above *extremely beautiful*, you should mark the space closest to beautiful, as follows:

BEAUTIFUL ☒☐☐☐☐☐☐ **UGLY**

If you consider the figure *extremely ugly*, you should mark the space closest to ugly, as follows:

BEAUTIFUL ☐☐☐☐☐☐☒ **UGLY**

If you consider the figure *quite beautiful*, you should mark the second space close to beautiful, as follows:

BEAUTIFUL ☐☒☐☐☐☐☐ **UGLY**

If you consider the figure *quite ugly*, you should mark the second space close to ugly, as follows:

BEAUTIFUL ☐☐☐☐☐☒☐ **UGLY**

If you consider the figure *slightly beautiful*, you should mark the third space close to beautiful, as follows:

BEAUTIFUL ☐☐☒☐☐☐☐ **UGLY**

If you consider the figure *slightly ugly*, you should mark the third space close to ugly, as follows:

BEAUTIFUL ☐☐☐☐☒☐☐ **UGLY**

If you consider the figure *not related* to any adjective of the pair, you should mark the central space, as follows:

BEAUTIFUL ☐☐☐☒☐☐☐ **UGLY**

If you have any doubt about these instructions, call the experimenter.

Thank you for your collaboration!

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