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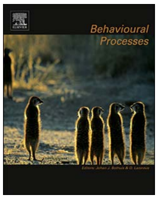

Effects of orientation and differential reinforcement on transitive stimulus control

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ABSTRACT

The emergence of transitive relations between stimuli that had never appeared together is a key process underlying concept formation. An unresolved theoretical issue with respect to transitive relations has been to determine whether differential reinforcement of stimulus-stimulus (S-S) relations though matching-to-sample, or contiguous S-S correlations/pairings, is more critical for producing transitivity. The current study inquired whether simple environmental S-S pairings, versus differential reinforcement of S-S relations, versus environmental S-S pairings with an orientation requirement, produced the greatest instances of transitivity. 12 groups of participants were parsed into one of four procedures (matching-to-sample, stimulus-paring, stimulus-pairing-w/response, stimulus-pairing-w/orientation) along one of three training structures (linear, many-to-one, one-to-many). All participants underwent a fixed number of training trials for establishing three, three-member stimulus sets (A1B1C1, A2B2C2, A3B3C3), followed by a single sorting test for AC transitivity. Our results demonstrate orienting towards environmental S-S pairings yield the greatest degree of transitivity. The effectivity of pairing procedures for establishing transitive relations, particularly when compared to matching-to-sample, can inform the development of educational interventions for individuals for whom the latter procedure (involving differential reinforcement) is ineffective.

1. Effects of orientation and differential reinforcement on transitive stimulus control

A long-standing goal for behavioral scientists has been the development of a satisfactory account of concept formation without recourse to mentalistic determinants (e.g., Hayes et al., 2001; Hull, 1920; Skinner, 1957; Smoke, 1932; Staats, 1961; Tonneau, 2001; Zentall et al., 2002). The formation of concepts, according to Kendler (1961), involves the "acquisition (and) utilization of a common response to dissimilar stimuli" (p. 447), where 'stimuli' are thought to constitute of physically grounded representations of ideas (Fields et al., 1984). Through the investigation of various stimulus-stimulus (S-S) relationships, such as a transitive S-S relation, the goal has been to understand how "ideas" (Fields et al., 1984, p. 143) relate to one another. Briefly, a transitive S-S relation describes the emergent relation between two stimuli based on their mutual associations with (at least) a third, mediating stimulus (Hayes et al., 2001; Hull, 1920; Mowrer, 1960; Sidman, 1994).

To illustrate what a transitive S-S relation may look like, imagine that a human participant is trained along the relation 'A goes with B' (A → B), whether through differential reinforcement (e.g., Amd et al., 2013) and or environmental S → S pairings (e.g., Pimenta and Tonneau, 2016). Next, imagine s/he is trained that 'B goes with C' (B → C). It follows that after learning A → B and B → C, our hypothetical participant may derive that A → C and C → A without further instruction – these constitute instances of transitive S-S relations. In the terminology of Fields et al. (1984), our hypothetical participant would have demonstrated "transitive stimulus control". Given their functional equivalence (Fields et al., 1984), the labels "transitivity" and "transitive stimulus control" will be used inter-changeably throughout the present manuscript. The current study explores yields of transitive stimulus control following exposure to one of four procedures (matching-to-sample vs. stimulus-pairing vs. stimulus-pairing-response vs. stimulus-pairing-orientation-response) parsed along three training structures (linear vs. one-to-many vs. many-to-one). We investigate whether differentially reinforcing S-S relations (Arntzen, 2012; Arntzen et al.,

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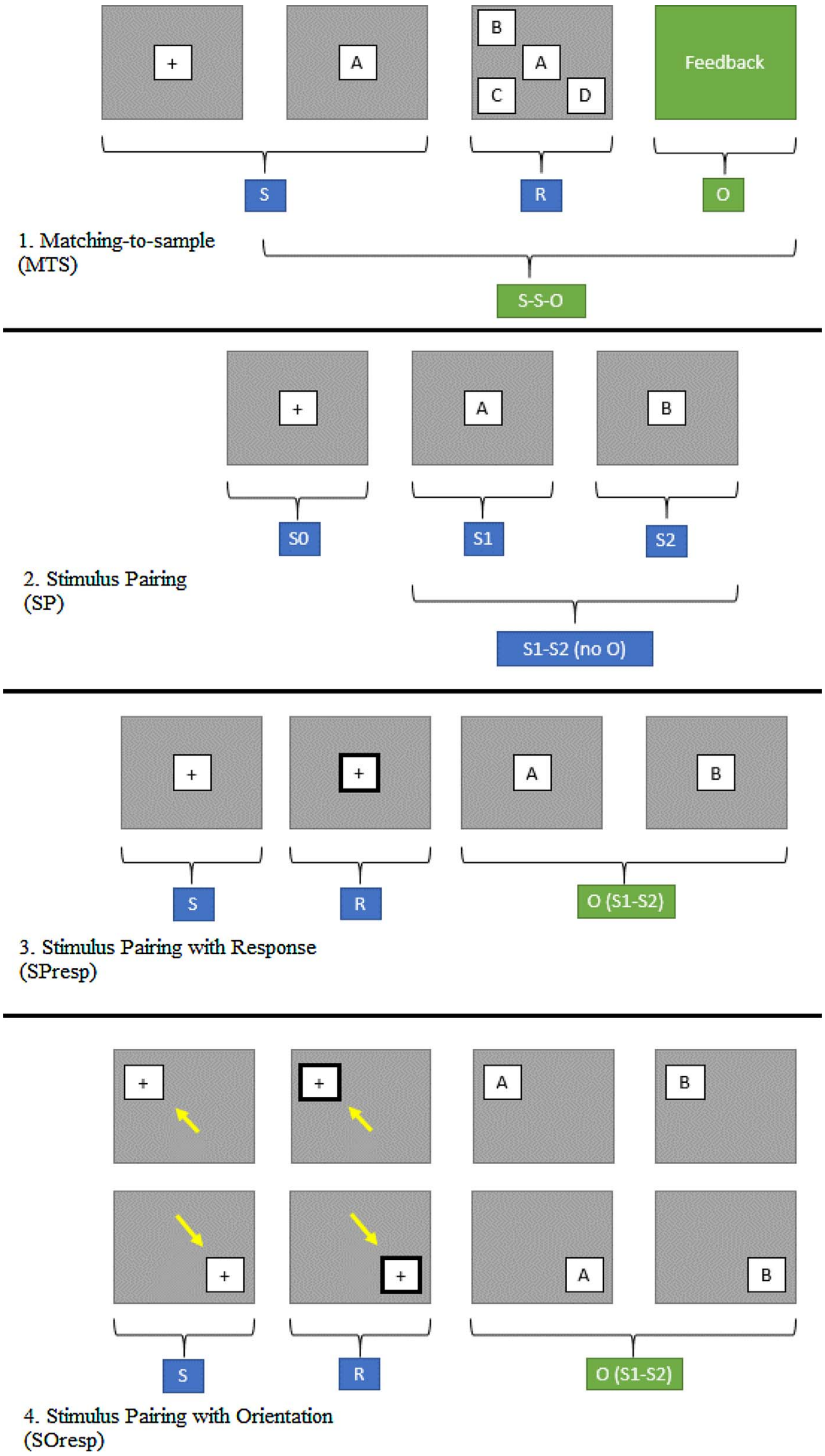

Fig. 1. Procedures compared in the current study. 'S', 'R' and 'O' refer to Stimulus, Response and Outcome, respectively. Only the MTS (Panel 1) differentially reinforced S-S relations. The SOresp (Panel 4) required an orienting response before stimulus pairs were presented. Both the SPresp (Panel 3) and SOresp procedures reinforced trial progression and the successive presentation of different S-S pairs. Only the SP (Panel 2) required no active responses from the participant in order to progress through trials.

2011; Nartey et al., 2015; Saunders and Green, 1999), or presenting stimulus pairs successively (Leader et al., 1996; Pimenta and Tonneau, 2016; Tonneau and González, 2004), or presenting stimulus pairs successively with a pre-programmed orientation requirement (cf., Sokolov, 1963), mitigates the emergence of transitivity (more on orientation responses later).

This line of questioning gained traction following a series of studies conducted by Leader and colleagues (Leader et al., 1996, 2000; Leader and Barnes-Holmes, 2001), where participants who had passively viewed S-S pairings yielded greater instances of transitive stimulus control when compared to participants exposed to a conventional matching-to-sample task, which employed differential reinforcement, although this finding has been disputed (Clayton and Hayes, 2004; Kinloch et al., 2013). Despite a considerable literature on the role of differential reinforcement in establishing S-S relations (e.g., Arntzen, 2012; Hayes et al., 2001; Leader and Barnes-Holmes, 2001; Kinloch et al., 2013; Saunders and Green, 1999; Sidman, 1994; Tonneau, 2001; Tonneau and González, 2004), inter-procedural differences make it difficult to draw any conclusive claims regarding the necessity of differential reinforcement towards demonstrating transitivity (Tonneau, 1993, 2001). Across those studies, participants who demonstrated transitivity generally did so after at least a single repetition of training-testing trials, incurring the possibility of exposure effects ("subtle reinforcement" – Clayton and Hayes, 2004, p. 581). Other potential confounds are the differences in the number of S-S relations trained/tested (Leader et al., 1996, 2000) and a lack of consideration of the *orienting* response (more on orientation later). Given the theoretical importance of transitive stimulus control in understanding concept formation vis-à-vis language (Hayes et al., 2001; Hull, 1920; Osgood, 1952; Sidman, 1994), a primary goal of the work described here was to replicate the attempts made by Leader et al. (1996, 2000), Clayton and Hayes (2004), and others (e.g., Kinloch et al., 2013) while controlling for the confounds described earlier.

Another procedural variable that can effect the emergence of S-S transitivity (cf., Saunders and Green, 1999) is the specific training sequence/structure involved via which S → S relations are presented (e.g., linear vs. one-to-many vs. many-to-one – see Kinloch et al., 2013). Presently, the consensus is that one-to-many (OTM) and many-to-one (MTO) structures yield greater instances of transitivity than linear (LIN) training structures, at least when a matching-to-sample procedure is used (Arntzen, 2012; Kinloch et al., 2013; Saunders and Green, 1999). No differences along training structure were reported for the respondent-type procedures described by Leader et al. (2000), presumably because training structure may be non-consequential in the absence of differential reinforcement. Nevertheless, given the differences across studies indicated earlier, it is worth re-examining whether training structures influence transitivity when S → S pairing procedures are used. Any differences across training structures for the pairing procedures tested here would suggest that the sequence of S → S pairings may mitigate transitivity independently of reinforcement, bringing to question as to why training structures were deemed important in the first place (again, see Saunders and Green, 1999).

Finally, it is worth mentioning that none of the published studies in this area made explicit provisions for the orienting response, a key component of effective Pavlovian conditioning (cf., Hilgard and Marquis, 1940; Sokolov, 1963; Wyckoff, 1952 also see Baccus et al., 2004). Given that orienting responses are elicited instead of entrained (Maltzman, 1979), they may be of use for entraining observing/discriminating responses in individuals otherwise minimally receptive towards instrumental contingencies (Dube et al., 2016; Dube and Mcllvane, 1999 across pigeons, Zentall et al., 1978). Humans, for instance, can readily produce observing responses following explicit instruction (Fantino et al., 1983), but only if they possess the capacity to verbally comprehend said instructions in the first place (Barth et al., 1995; Devany et al., 1986). For those unable to understand verbal instructions, or discriminate effectively between differentially reinforced responses (Dube et al. 2016), environment-elicited orienting reflexes (Maltzman, 1979) may be utilized to develop relational learning programs that do not require differential reinforcements. This is a primary reason orientation was selected as a procedural manipulation in the current study.

The study described here constituted of a between-groups design comparing transitivity yields across twelve groups of participants. These groups were parsed along four procedures and three training sequences (see Method). Out of the four procedures tested, only a matching-to-sample (MTS) involved differential reinforcement of S-S relations (Carrigan and Sidman, 1992, p. 202). The three remaining procedures, which did not differentially reinforce stimulus relations, consisted of successively presentations of stimulus pairs (Fig. 1). One of these included a stimulus pairing procedure with an orienting response (SOresp – Fig. 1). Comparing the outcomes produced by participants undergoing MTS and SOresp procedures allowed us to directly compare the influence of differential reinforcement and orientation towards demonstrating transitivity.

In the present study, all participants first underwent a training-testing phase involving natural categories in order to familiarize them with group-specific procedure demands while reducing inter-individual variability regarding task comprehension. This was followed by a training-testing phase with abstract stimuli. To minimize exposure effects, all participants underwent a single sorting test trial for transitivity following a fixed number of training trials for both the natural and abstract stimulus categories. Sorting tests can obviate the influence of repeated exposure effects given that a single test trial is involved (Arntzen et al., 2015). Sorting tests appear to be as reliable a measure of transitivity as multiple MTS test trials, mitigating the latter's concern with exposure effects (Arntzen et al., 2016, 2015; Nartey et al., 2015).

To summarize, our goal here was to determine whether the procedure used for establishing S-S transitivity interacts with the sequence of S-S relations trained, and whether there are significant differences in transitivity yields between procedures and/or training structures. Unlike previous investigations into this area, we controlled for test retest exposures (e.g., Clayton and Hayes, 2004) and task familiarity (e.g., Leader and Barnes-Holmes, 2001) while isolating the influence of orienting towards the S-S pairs presented versus simply presenting the S-S pairs only (Leader et al., 1996, 2001).

2. Method

2.1. Participants

86 participants were recruited via personal invitation through a university-affiliated online platform at the Federal University of Sao Carlos (UFSCAR). The data of 14 participants were excluded due to programming and instruction errors, leaving a final sample of 72 (age range: 18–24, 49 females) non-Psychology undergraduate students. This corresponds with the sample size recommendations from a prospective power analysis for a one-way ANOVA, with $f = 0.45$, power = 0.9, factors = 4 and $\alpha = 0.05$ (Faul et al., 2007). All participants were healthy with normal and corrected-to-normal vision. Interested volunteers provided written consent prior to participation. Participants received a chocolate (or vanilla) bombom™ upon completion. The procedures and recruitment methods described here were approved by the regulatory ethics committee at UFSCAR.

2.2. Apparatus

All tasks were designed on the E-Prime platform (Schneider et al., 2002). The nine nonsense trigram stimuli (A1, A2, A3, B1, B2, B3, C1, C2, C3) were presented in a black, Times Roman font (22) on a white background. These trigrams were ZEK, SLG, AKU, JOV, NIS, PVI, NVZ, AKA and DKS. The nine natural category stimuli (fruit 1, fruit2, fruit3, car1, car2, car3, tool1, tool2, tool3) were procured from the free image repository at Getty Images®. These 18 stimuli appeared on screen during training trials, but were also printed in colour on 3.3 × 4.7″ laminated cards to be used during sorting/transitivity tests. The procedures described were carried out on one of three Windows-based laptops with screen sizes ranging from 13.3 to 15.5″, and took place in the LECH laboratories at the Department of Psychology at UFSCAR.

2.3. Procedure

All participants underwent the same numbers of training and testing trials. This involved 60 training trials with natural categories, followed by a sorting test where participants had to sort exemplars from the same natural categories together (e.g., fruit1 with fruit3, tool1 with tool3, and so on). This was followed by 60 training trials with abstract stimuli

(A1/A2/A3/B1/B2/B3/C1/C2/C3), followed by a second sorting test where participants had to pair the A and C stimuli together. Procedure and structure was varied across 12 groups, with each group constituting of six participants. The groups were labelled and numbered as SP-LIN (Group 1), SP-OTM (Group 2), SP-MTO (Group 3), MTS-LIN (Group 4), MTS-OTM (Group 5), MTS-MTO (Group 6), SPresp-LIN (Group 7), SPresp-OTM (Group 8), SPresp-MTO (Group 9), SOresp-LIN (Group 10), SOresp-OTM (Group 11) and SOresp-MTO (Group 12).

The three training structures tested here involved linear (LIN), one-to-many (OTM) and many-to-one (MTO) sequences. Specifically, a linear (LIN) sequence involved training A1 → B1, B1 → C1, A2 → B2, B2 → C2, A3 → B3 and B3 → C3; one-to-many (OTM) involved training B1 → A1, B1 → C1, B2 → A2, B2 → C2, B3 → A3 and B3 → C3; many-to-one (MTO) involved training A1 → B1, C1 → B1, A2 → B2, C2 → B2, A3 → B3 and C3 → B3. The four procedures tested were Stimulus-Pairing (SP), Stimulus-Pairing with Response (SPresp), Stimulus-Orienting with Response (SOresp) and Matching to Sample (MTS). These are described in detail below.

Stimulus Pairing (SP). The SP procedure was directly adapted from the procedures employed by Leader et al. (1996, 2000) and Leader and Barnes-Holmes (2001) and others (Clayton and Hayes, 2004). It commenced with the following instructions presented on a computer screen (all instructions translated from Portuguese)

> "Welcome. During this task, please pay attention to the center of the screen. Please contact the experimenter when the program terminates. Press any button to begin…"

Following a keypress, participants viewed a black fixation cross on a white background for 3000 milliseconds (ms), followed by the onset of a stimulus from a natural category (i.e., fruit/car/tool) for 1000 ms. A blank screen followed for 500 ms. Next, a second stimulus (from the same category as the first) appeared for 1000 ms, followed by a 3000 ms fixation, marking the end of a trial. Following 60 trials involving natural categories, the program instructed participants to call in the experimenter. The experimenter would come in and present participants with six cards (fruit1, fruit3, car1, car3, tool1 and tool3, in no specific order) with the verbal instruction "please organize these cards into three pairs". The experimenter would then leave the room until the participant declared that s/he was finished. The experimenter would return, take a picture of the card pairs, then tell participants "you will now continue the same task but with new images. Please pay attention to the images on the screen. Now press any key when you are ready to continue." Following a keypress, the second part of the task began. Similar to the earlier segment, all participants underwent 60 trials involving S-S pairings. For example, the SP-LIN group viewed the A1-B1, A2-B2, A3-B3, B1-C1, B2-C2 and B3-C3 pairs in randomized order.

Completion of 60 trials was followed by an automated prompt to call the experimenter. As before, the experimenter provided participants with a six card deck with the instructions to form three pairs and left the room. The cards contained the A1, A2, A3, C1, C2 and C3 stimuli. After the participant was finished, the experimenter returned to the room and took a photo of the card pairs on the table. This signalled the end of the experiment.

Matching to Sample (MTS). Adapted from the MTS procedures employed in Leader and Barnes-Holmes (2001), which did not incorporate an orientation response (unlike the MTS employed by Minster et al., 2011). The MTS commenced with the following instructions presented on screen (translated from Portuguese)

> *"Welcome. In this task, you will first see an image near the top part of the screen. Next, you will see three images near the bottom of the screen. You have to select from one of the three images to continue. If your selection is correct, you will see the message 'correto'. If your selection is wrong, you will see a red 'x'. To select the image on the left, press 'b'. To select the image in the middle, press 'n'. To select the image on the right, press 'm'. When the program terminates, please call the experimenter. Press any key to begin"*

Following a keypress, participants would be presented with a sample stimulus from a natural category (e.g., fruit1) near the top half of the screen for 1500 ms. Next, three comparisons, one from the corresponding category (e.g., fruit2) and two from different categories (e.g., tool1, car2) appeared near the bottom of the screen. All stimuli remained on screen until the participant produced an appropriate keypress response ('b', 'n', 'm' on the keyboard) to select the left, middle or right comparison, respectively. This was followed by a feedback message for 1000 ms (displaying 'correto', or a red 'x', if the previous response was correct, or incorrect). Finally, a black fixation cross appeared on the screen for 3000 ms, marking by the onset of the subsequent trial. This was followed by a sorting test, followed by 60 trials involving conditional simultaneous discriminations involving the ABC stimuli. The second sorting test followed completion.

Stimulus Pairing with Response (SPresp). The SP procedure described earlier was modified in two ways and administered across Groups 7 (LIN), 8 (OTM) and 9 (MTO). First, in order to prevent temporal conditioning artefacts (cf., Balsam, 1984), the inter-stimulus interval (ISI) between the two stimuli in a sequence pair was jittered between 500 and 1500 ms rather than being kept at a static 1000 ms. Second, participants were required to click on the fixation cross when it appeared on screen in order to progress through the task. Doing so consequated a S-S sequence, which was not *specific* to the response emitted (Saunders and Green, 1999, p. 121). A response emitted during this stage may be thought of as reinforcing sequence progression non-specifically. To understand the discrepancy between specific and non-specific reinforcement assumed here, note how in a MTS procedure, emitting a response reinforces both a S-S relation, specifically, as well as progression through the trial sequence, non-specifically (Saunders and Green, 1999, p. 121). The purpose behind incorporating a sequence-progression reinforcement contingency in the current procedure was to test whether non-specific reinforcement of trial progression could affect performances relative to the other procedures tested here. The SPresp commenced with the following instructions presented to participants on screen

> "Welcome. In this task, you will see a ' + ' symbol on the screen. Please click on the ' + ' with the mouse to continue. When the program terminates, please call the experimenter. Press any key to begin."

Following a key press, participants viewed a black fixation cross on a white background and a mouse pointer. This remained on screen until a mouse click was recorded by the computer. Following a click, the pointer disappeared and a stimulus appeared near the screen center for 1000 ms. This was followed by the ITI that jittered along 50 ms intervals within a 500–1500 ms window, followed by the appearance of the second stimulus for 1000 ms. This was followed by the re-appearance of a blank fixation screen for 500 ms, signalling the end of a trial. Participants underwent training-testing sequences similar to those already described.

Note that, contrary to the instructions provided, the location of the mouse pointer when the physical mouse was clicked was not restricted to the area in which the cross appeared (unlike the SOresp – see below). In other words, a mouse click anywhere on the screen would progress the trial. Hence, if generalized reinforcement of trial progression (versus differential reinforcement of S-S relations) was played a significant role in determining transitive control, then the SPresp and the SOresp (see below) should yield similar yields of transitive stimulus control.

Stimulus Orientation with Response (SOresp). The SPresp was modified to incorporate an orientation response prior to the presentation of the S-S sequence (e.g., Griffin, 1981). In the SOresp, the fixation cross on the first screen would appear along one of four regional quadrants on screen rather than the center (Panels 3 and 4; Fig. 1).

Participants received the same instructions as those who underwent the SPresp, where they were instructed to click on the cross to continue. Unlike the SPresp however, mouse clicks were registered only if they were made when the mouse pointer was located in the specific quadrant where the fixation had previously appeared. A registered click initiated a S-S sequence in the same quadrant as the fixation had appeared earlier (Panel 4; Fig. 1). The location of the cross was randomized across trials, with the cross never re-appearing in the same quadrant twice in succession (see Baccus et al., 2004, for a similar setup). Participants underwent 60 training trials and a sorting test with natural categories, followed by 60 training trials and a second sorting test with abstract stimuli.

3. Results

Participants in the SP, SPresp and SOresp underwent 60 training trials without differential feedback. Across the 18 participants who underwent 60 training trials with differential feedback across the MTS conditions, the range of correct responses during training ranged from 54 to 60. The percentage of accurate responding for the MTS condition never fell below 90%, which corresponds with acquisition criteria typical to stimulus equivalence research (Fields et al., 1984, 2014). Individual accuracies are presented in Table 1. When viewing Procedure only, SOresp yielded the highest accuracies (35), followed by SP (21), SPresp (18) and MTS (13). When viewing Structure only, the highest accuracies were produced by OTM (33), LIN (28) and MTO (26), in that order. The Procedure + Structure combination yielding the highest accuracies was SOresp + MTO (14), then SP + OTM (11), SPresp + LIN (7), and MTS + MTO/MTS + OTM (5/5).

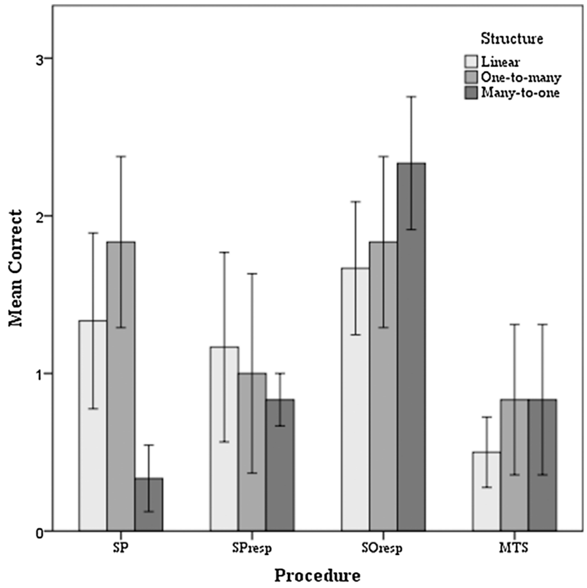

Fig. 2. Mean number of correct pairs (*y*-axis) across four procedures (*x*-axis) and three training structures (legend). Error bars indicate witihn-group variability (± 1 * SEM).

Table 1
Transitivity test accuracies across Procedure, Structure and Group.

ID	Procedure[a]	Sequence	Correct[b]	ID	Procedure	Sequence	Correct
101	SP	LIN	3	701	SPresp	LIN	0
102	SP	LIN	3	702	SPresp	LIN	3
103	SP	LIN	0	703	SPresp	LIN	3
104	SP	LIN	1	704	SPresp	LIN	1
105	SP	LIN	1	705	SPresp	LIN	0
106	SP	LIN	0	706	SPresp	LIN	0
201	SP	OTM	1	801	SPresp	OTM	0
202	SP	OTM	1	802	SPresp	OTM	3
203	SP	OTM	0	803	SPresp	OTM	3
204	SP	OTM	3	804	SPresp	OTM	0
205	SP	OTM	3	805	SPresp	OTM	0
206	SP	OTM	3	806	SPresp	OTM	0
301	SP	MTO	1	901	SPresp	MTO	1
302	SP	MTO	1	902	SPresp	MTO	1
303	SP	MTO	0	903	SPresp	MTO	1
304	SP	MTO	0	904	SPresp	MTO	1
305	SP	MTO	0	905	SPresp	MTO	0
306	SP	MTO	0	906	SPresp	MTO	1
401	MTS	LIN	0	1001	SOresp	LIN	3
402	MTS	LIN	0	1002	SOresp	LIN	1
403	MTS	LIN	1	1003	SOresp	LIN	1
404	MTS	LIN	1	1004	SOresp	LIN	1
405	MTS	LIN	1	1005	SOresp	LIN	1
406	MTS	LIN	0	1006	SOresp	LIN	3
501	MTS	OTM	3	1101	SOresp	OTM	3
502	MTS	OTM	0	1102	SOresp	OTM	3
503	MTS	OTM	0	1103	SOresp	OTM	3
504	MTS	OTM	0	1104	SOresp	OTM	1
505	MTS	OTM	1	1105	SOresp	OTM	0
506	MTS	OTM	1	1106	SOresp	OTM	1
601	MTS	MTO	1	1201	SOresp	MTO	3
602	MTS	MTO	0	1202	SOresp	MTO	3
603	MTS	MTO	0	1203	SOresp	MTO	3
604	MTS	MTO	3	1204	SOresp	MTO	1
605	MTS	MTO	1	1205	SOresp	MTO	3
606	MTS	MTO	0	1206	SOresp	MTO	1

[a] SP – Stimulus Pairing; MTS – Matching-to-Sample; SP_resp – Stimulus Pairing with Response; SO_Resp – Stimulus Observation with Response.
[b] Number of correct pairs produced.

We conducted two one-way analyses of variance (ANOVAs) to determine whether the number of correct pairs produced significantly differed when collapsed across training structure *or* procedure (Fig. 2). Data is presented as mean ± standard deviation. The data were not normal, as determined by Shapiro-Wilk ($p > 0.05$). When collapsing across structures, which met the homogeneity of variance assumption (Levene's = 2.62, $p = 0.08$), there was no significant effect across the linear (1.17 ± 1.17), one-to-many (1.38 ± 1.35) and many-to-one (1.08 ± 1.21) sequences, F (2, 69) = 0.371, $p = 0.692$. When collapsing across procedures, which also showed homogeneity of variance (Levene's = 1.13, $p = 0.345$), a significant effect across SP (1.17 ± 1.25), SPresp (1.00 ± 1.19), SOresp (1.94 ± 1.11) and MTS (0.72 ± 0.96), was found, F (3, 68) = 3.859, $p = 0.013$, $f = 0.387$. Tukey post hoc analyses revealed that the correct pairs produced by participants undergoing the SOresp were significantly greater ($p = 0.01$) than those undergoing the MTS (Fig. 3). The differences from pairwise contrasts between the other procedures did not reach significance.

4. Discussion

The current experiment compared four procedures (SP/MTS/SPresp/SOresp), parsed along three training structures (LIN/OTM/MTO), to see whether there were significant differences in the number of correct pairs produced. When collapsing procedures along structure, the OTM yielded the greatest number of correct pairs, although this was not significant. When collapsing structures along procedure (Fig. 3), a significant effect was found. Pairwise comparisons between procedures revealed that the SOresp produced significantly more correct pairs than the MTS. Our findings bring to light the role of differential reinforcement towards the emergence of transitive stimulus control. Our work supports the claim that environmental S-S correlations can suffice to establish the relations required for demonstrating transitivity (cf., Tonneau, 2001; Mowrer, 1960). We add to Tonneau's position by highlighting the facilitative role of orientating (Sokolov, 1963) towards relevant S → S correlations.

The role of differential reinforcement towards yielding transitive stimulus control is a key assumption underlying some contemporary behavior-analytic approaches towards language and concept formation

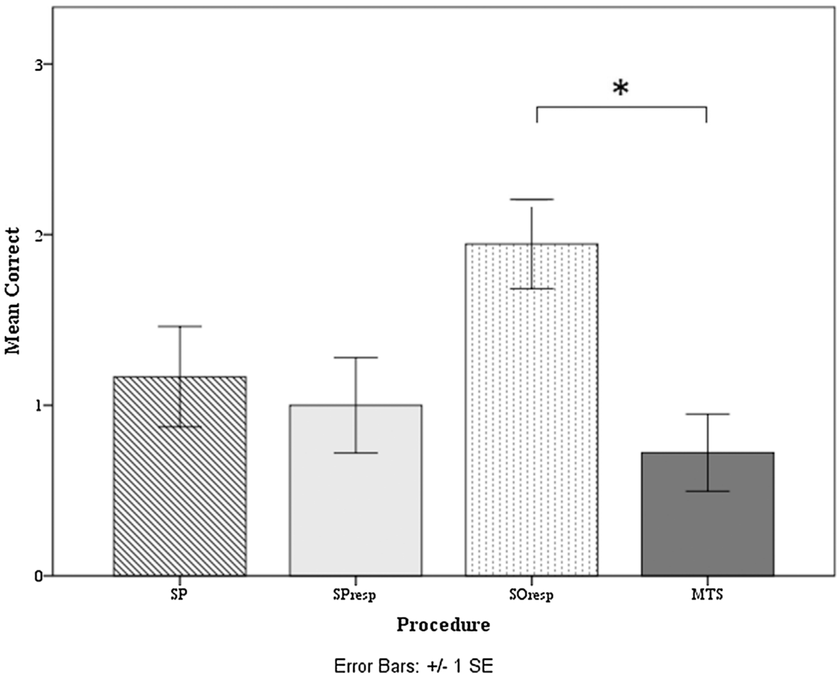

Fig. 3. Mean number of correct pairs (y-axis) produced with the three structures collapsed across the four procedures (x-axis). The stimulus pairing with orienting (SOresp) procedure yielded significantly ($p < 0.02$) more correct pairs than the matching-to-sample (MTS). All other comparisons were non-significant.

(cf., Relational Frame Theory, or RFT, Hayes et al., 2001; Stimulus Equivalence, or SE, Sidman and Tailby, 1982; but see Mowrer, 1960). In contrast to some other perspectives (e.g., Das and Nanda, 1963; Killeen, 2014; Mowrer, 1960; Resorla and Solomon, 1967; Staats, 1961; Staddon, 2014), both SE and RFT maintain Skinner's (1957) distinction between classical and instrumental conditioning (Hayes et al., 2001, p. 9), with the latter (involving differential reinforcement) assumed to enhance the emergence of transitive relations (Hayes et al., 2001) –28; also see Donahoe et al., 1997). The findings reported here correspond with outcomes observed elsewhere (e.g., Minster et al., 2006; Minster et al., 2011; Pimenta and Tonneau, 2016; Tonneau and González, 2004). They raise the question of how necessary differential reinforcement is for forming S-S relations in the first place (Mowrer, 1960; Tonneau, 2001).

Two additional points require mention. First, recall that the stimulus pairing (SP) procedure here required participant to passively observe pairs of successively presented stimuli. Interestingly, the number of correct pairs produced by the SP group was greater than those produced by the SPresp group, although this difference did not reach significance. The SPresp, relative to the SP, required a response in order for trial sequences to progress. While admitting the possibility that the difference may be statistical noise, it nevertheless raises the question as to whether reinforcing trial progression may somehow retard the formation of transitive relations. Perhaps only the second stimulus in the S → S sequence in the SResp procedure attained discriminative control, given that orienting towards it was reinforced explicitly (Balkenius, 2000). By the same logic, since the S → S pairs in the SP procedure did not require any discriminative responses, attention may not have localized to any specific member of the pair *per se*, thereby facilitating observation towards both members of the S → S sequence (again, see Balkenius, 2000; also see Dube and McIlvane, 1999; Maltzman, 1967).

A second question involves asking elaborating on why *orienting* was selected as the key procedural manipulation here instead of *observing*, given the latter is more typical to operant research (e.g., Wyckoff, 1952). First, relative to observing responses, which are volitional and behaviorally more complex (Maltzman, 1979), orienting responses can be elicited through manipulations of stimulus configurations, spatial positioning, and presentation intervals (Bradley, 2009; Sokolov et al., 2002). None of these manipulations require differential reinforcement of the preceding responses. Second, as mentioned earlier, we wished to test the effectivity of a procedural component (orientation) that could be used to entrain S-S relations without requiring sensitivity to differential reinforcement contingencies. Our results demonstrate Pavlovian procedures for training S-S relations which incorporate orienting responses appear to be as effective, if not more so, then matching-to-sample procedures involving differential reinforcement. This can be of use for populations having difficulty with instrumental learning (e.g., learning observing responses – Dube et al., 2016). Future researchers can investigate whether expectant observing responses can be learned following multiple orientations towards a target stimulus pattern (Eckerman et al., 1968), thereby highlighting the continuity between involuntary orienting, and voluntary observing, responses (Maltzman, 1979).

Some potential limitations of the present study are described. First, while our findings correspond with the findings reported by Leader et al. (1996), in that a respondent procedure yielded greater transitivity than an instrumental one, recall that the work reported by Clayton and Hayes (2004) showed the reverse effect when the number of members in a stimulus class were increased. This implies that, perhaps for larger stimulus classes, differential reinforcement may be necessary to “strengthen” the S-S relations (cf., Osgood, 1952; Skinner, 1957 but see Mowrer, 1960). On balance, the MTS employed by Clayton and Hayes required two orienting responses, along with instrumental reinforcement, while training S-S relations. In their study, participants had to click on the sample stimulus with the mouse pointer (orient-1), followed by another click on the comparison stimulus (orient-2), followed by differential reinforcement. It may be the case that the positive results reported by Clayton and Hayes were driven, at least in part, by orienting responses *and* differential reinforcement. On that note, our matching-to-sample here did not incorporate orienting responses. We did this in order to isolate the roles of differential reinforcement and orienting responses. The results obtained here can inform a future study where a conventional MTS with orienting requirements (e.g., Kinloch et al., 2013) can be compared with the SOresp described here to determine whether orienting interacts with differential reinforcement in order to enhance, reduce, or have no differential effect, on measurements of transitivity.

Second, the number of reinforced conditional discriminations may appear insufficient towards establishing a class containing of transitively related stimuli (e.g., Sidman and Tailby 1982). In response, first note that the most incorrect pairs recorded for a single participant from the MTS group was 6, across a block total of 60 trials. The binomial probability for this outcome is < 0.000001, given the assumption of correct responding being determined by random chance ($P = 0.5$). This suggests that responding was well under discriminative stimulus control (Sidman, 1980). Second, our MTS biased conditional discrimination training towards stimulus class formation (Carrigan and Sidman, 1992) by presenting two negative comparisons alongside one positive comparison on every trial to reduce the likelihood of negative comparison control (Johnson and Sidman, 1993), and by varying the positioning of all comparisons while excluding novel distractors. For example, we used $\underline{\text{A1}} \rightarrow \underline{\text{B1}}\text{B2B3}$ and $\underline{\text{A1}} \rightarrow \text{B3}\underline{\text{B1}}\text{B2}$ training instead of $\underline{\text{A1}} \rightarrow \text{X1}\underline{\text{B1}}\text{B3}$ or $\underline{\text{A1}} \rightarrow \underline{\text{X2}}\text{B2B3}$ training, where X1 and X2 are representative of novel negative and positive comparisons, respectively (Carrigan and Sidman, 1992, p.203). Third, since everyone in the MTS group had been exposed to a fixed number of MTS training trials, the likelihood of stimulus sets emerging due to responding *ipso facto* is low (Saunders et al., 1988). The outcomes suggest that participants in the MTS group were under discriminative stimulus control of the A → B and B → C reinforcement contingencies (Saunders and Green, 1999). Finally, the pre-training phase involving natural categories may have affected the present results given that mere exposure to stimulus-stimulus patterns can lead to the formation of associated sets, regardless of instrumental feedback (e.g., Saunders et al., 1988). On balance, our reason for including pre-training was to familiarize participants with the testing format, thereby promoting task comprehension. Furthermore, since all participants underwent pre-training, any potential confounds arising from the pre-training were spread across participants and between groups.

Future research could address some of these limitations in the following ways. First, the number of stimuli within a set could be increased (e.g., from three to five members) to determine whether- specifying S-S relations through differential reinforcement becomes more important for larger sets/classes. Second, sorting tests could incorporate distracter cards in the manner A1A2X1C1C2X2, where X1 an X2 would constitute of novel stimuli that the participant had not encountered earlier. Third, one could contrast the MTS like the one used by Clayton and Hayes (i.e., with two orientation responses and differential reinforcement) with the SOresp procedure used here. This would answer whether differential reinforcement, relative to orientation, is unimportant, or incremental, or perhaps even detrimental (as indicated presently) towards producing transitivity. Either outcome would clarify the role of differential reinforcement towards transitive stimulus control, which has both theoretical (Tonneau, 2001) and practical (Dube and McIlvane, 1999; Nielson, 2011) implications.

Another matter future work could address is the contribution of differential reinforcement and orientation towards the transfer of affect across transitively related stimuli (e.g., Amd et al., 2013; Amd and Roche, 2016a, 2016b; Das and Nanda, 1963; Dougher et al., 1994; Hayes et al., 2001; Staats and Staats, 1958; Staats, 1961). Such a study would address the claim that both reinforcement and transitivity are prerequisites for transfer (Donahoe et al., 1997; Hayes et al., 2001; Sidman, 1994, but then see Mowrer, 1960; Pimenta and Tonneau, 2016; Tonneau and González, 2004). Future research can look at the interaction between differential reinforcement, transitivity, and orientation on transfer effects to determine which of those procedural variables are more important for yielding the latter.

5. Conclusion

The work reported here highlights the role of orientation (Sokolov, 1963; Sokolov et al., 2002) in contiguous S-S learning (e.g., Tonneau, 1993) as an important consideration in any behavioral analysis of S-S relations vis-à-vis transitivity. It may well be that orienting functions as the "guiding principle for deciding when (stimulus) contiguity will and when it will not result in learning" (Mowrer, 1960, p. 169). The importance of developing procedures to clarify across competing theoretical accounts of stimulus-stimulus relations and their emergent behavioral products (e.g., transitivity, transfer) can inform behavioristic accounts of concept formation specifically (Zentall et al., 2002), and of memory and cognition more generally (e.g.,Amsel, 1994; Holt, 1914; Hull, 1920; Mowrer, 1960; Tonneau, 1993; Warren, 1921). On a practical level, we hope that the current results can be used to inform the development of educational methods to facilitate relational learning in individuals who are insensitive to conditional discrimination training (Devany et al., 1986).

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