

## Effects of orientation and differential reinforcement II: transitivity and transfer across five-member sets

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### ABSTRACT

A recent report by Amd et al. (2017) demonstrated that orienting towards successively presented stimulus-stimulus pairs yielded significantly more transitive relations than when those same pairs were differentially reinforced following training for three, 3-member stimulus sets. We build on that work in four important ways. First, transitivity yields produced by Pavlovian and instrumental procedures were compared following training for three 5-member sets (A1-B1-C1-D1-E1, A2-B2-C2-D2-E2, A3-B3-C3-D3-E3), where the 'A' stimuli were emotional faces and all remaining stimuli were nonsense words. Second, our instrumental task here required two orienting/observing responses per trial. Third, we compared differences in multi-nodal transfer following Pavlovian and instrumental relational learning procedures. Finally, we tested whether functioning as 'end terms' in a relational series can mitigate transfer following instrumental conditioning. Transitivity, as measured by sorting tests, was significantly more pronounced following Pavlovian training. Transfer, assessed before and after relational training with two visual analog scales corresponding to valence and arousal dimensions, appeared marginally more robust observed for participants exposed to the Pavlovian condition. Transfer magnitude was positively related with demonstrations of transitivity, regardless of type of conditioning.

### 1. Introduction

Concept formation involves deriving transitive relationships between indirectly related stimulus events (e.g., Fields et al., 1984; Barnes-Holmes, et al., 2001; Kendler, 1964, 1961). It may also involve the contextually-modulated transfer of emotional properties across related events (Amd et al., 2013; Amd and Roche, 2016; Bortoloti and de Rose, 2011; Dougher et al., 1994; Barnes-Holmes et al., 2001; Mowrer, 1960, pp. 62–64; Staats, 1961). For an example of a transitive relation, imagine some stimulus A that is related to a second stimulus B ( $A \rightarrow B$ ). If B were then related to a third stimulus C ( $B \rightarrow C$ ), inferring that A and C are related ( $A \rightarrow C$ ,  $C \rightarrow A$ ) would constitute an instance of transitivity (Amd et al., 2017; Fields et al., 1984).

To illustrate *transfer*, imagine that the A stimulus from the above example had been systematically paired with emotionally evocative images. Under certain conditions (cf., Rozin et al., 1998), correlating a non-salient stimulus (A) with an emotionally salient image can cause stimulus A to elicit emotional responses topographically similar to those elicited by the unconditioned emotion-eliciting image (Amd et al., 2013, p.329; also see Martin and Levey, 1978; Mowrer, 1960; Staats and Staats, 1959; Tonneau, 1993). When a formerly neutral stimulus

elicits evaluative responses following direct pairings with an unconditioned stimulus/image (US), 0-node transfer has occurred (Amd and Roche, 2015, p. 538; also see Davey, 1992; De Houwer, et al., 2001, 2001; Staats et al., 1962; Tyndall et al., 2009). Alternatively, if evaluative responses are later observed in the presence of stimuli indirectly related to the emotional US, such as the C stimulus in the previous example which was transitively related to A, we can declare that transfer has occurred across multiple nodes (1-node transfer; Amd et al., 2013, p. 330). Note that a 'node' in the present work refers to the number of mediating stimuli between the tested members of a series (Fields et al., 1984 pp. 146–47). Transitivity and transfer effects across directly (0-node) and indirectly ( $\geq 1$ -node) associated stimuli have been foundational to behavioristic accounts of language and cognition (e.g., Barnes-Holmes et al., 2001; Das and Nanda, 1963; Mowrer, 1960; Pimenta and Tonneau, 2016; Staats, 1961). Our goal here is to contribute to those accounts by continuing our analysis of some procedural variables deemed important towards producing transitivity and transfer, namely differential reinforcement (Hayes et al., 2001; Sidman, 2000) and stimulus-stimulus ( $S \rightarrow S$ ) contiguity (Tonneau, 1993, 2001).

We expand here upon a recent report by Amd and et al., (2017) which highlighted the facilitative role of orienting responses

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(Maltzman, 1979) in human S-S learning. In that study, four groups of participants underwent an instrumental matching-to-sample (requiring a keypress response) and three variations of Pavlovian S-S pairing tasks. All groups first underwent a pre-training and sorting test phase with their respective procedures using natural category exemplars (e.g., fruits, tools) so that task demands were understood. During actual training, all participants underwent a fixed number of trials for establishing three 3-member stimulus sets (A1-B1-C1/A2-B2-C2/A3-B3-C3). Participants next had to produce three pairs from a shuffled deck of six cards containing A1-A2-A3-C1-C2-C3, where a pair was deemed correct if it corresponded with the relational training provided earlier (e.g., A1-C1). We found participants who oriented towards successively presented stimuli produced significantly more correct card pairs than those who underwent matching-to-sample (Amd et al., 2017, pp. 61–62. All subsequent page numbers, unless otherwise indicated, refer to that study). Unlike some earlier investigations on the influence of differential reinforcement and S-S contiguity towards producing transitivity and transfer (e.g., Arntzen et al., 2011; Clayton and Hayes, 2004; Leader et al., 1996, 2000; Kinloch et al., 2013), our previous work fixed the number of training and test trials to minimize exposure effects (Clayton and Hayes, 2004, p. 581). To enhance task comprehension, all participants in that study underwent pre-training using natural category exemplars (e.g., fruit1 → fruit 2, tool1 → tool2) before proceeding to relational training with nonsense words (e.g., A → B, B → C). Although our previous finding highlighted the facilitative role of orienting during relational learning (Maltzman, 1979), three potential limitations of that work are worth noting.

First, the reported differences in transitivity yields for three-member stimulus sets leaves open the question as to whether differential reinforcement of S-S relations becomes more important when set size/complexity is increased (e.g., Amd and Roche, 2015; Clayton and Hayes, 2004), perhaps through the ‘strengthening’ of the S-S relation (Barnes-Holmes et al., 2001, but see Shahan, 2017). Second, our MTS had differentially reinforced S-S relations following keypress responses, similar to Leader et al., (1996, 2001), and thus did not systematically require orienting/observing responses to progress, unlike more recent iterations of the MTS, which presumably requires orienting towards the sample and comparison stimuli (e.g., Kinloch et al., 2013). Finally, our tests for transitivity had required participants to form three pairs from a deck of six cards, which could not assess if *all* predicted transitive relations had emerged. For example, in a deck of cards containing A1-A2-A3-C1-C2-C3 where the correct pairs would be A1-C1, A2-C2 and A3-C3, the formation of any two pairs accurately would cause the third pair as correct by default. It would be unknown, in this case, whether the third transitive relation had been derived.

The current study addresses the above limitations while furthering our understanding of differential reinforcement and S-S contiguity towards producing transitivity and transfer effects. Participants presently underwent one of two relational learning procedures aimed to establish three 5-member stimulus sets in the manner  $A \rightarrow B$ ,  $B \rightarrow C$ ,  $B \rightarrow D$ , and  $D \rightarrow E$ . Across each set, the ‘A’ stimuli consisted of happy, neutral and sad faces (obtained from Lundqvist et al., 1998); the remaining B, C, D and E stimuli were nonsense words. The three stimulus sets were categorized by the valences of their respective ‘A’ stimuli – furthermore, the C and D stimuli were nodally equidistant from the unconditioned A stimuli across all sets trained (Fig. 1). Following a fixed number of training trials, transitivity was assessed through card sorting, similar to our previous work (p. 61; also see Arntzen et al., 2017; Nedelcu et al., 2015), but with added ‘distractor’ cards for reducing the probability of correct responses appearing by chance. Transfer was assessed through self-reported valence and arousal ratings collected before and after participants completed relational learning using visual analog scales. Earlier reports showed 0-node and  $\geq 1$ -node transfer can occur in the presence (Amd et al., 2013; Dougher et al., 1994; Barnes-Holmes et al., 2001) and absence (Das and Nanda, 1963; LeDoux et al., 1984; Tonneau and Gonzalez, 2004; Staats and Staats, 1958) of differential

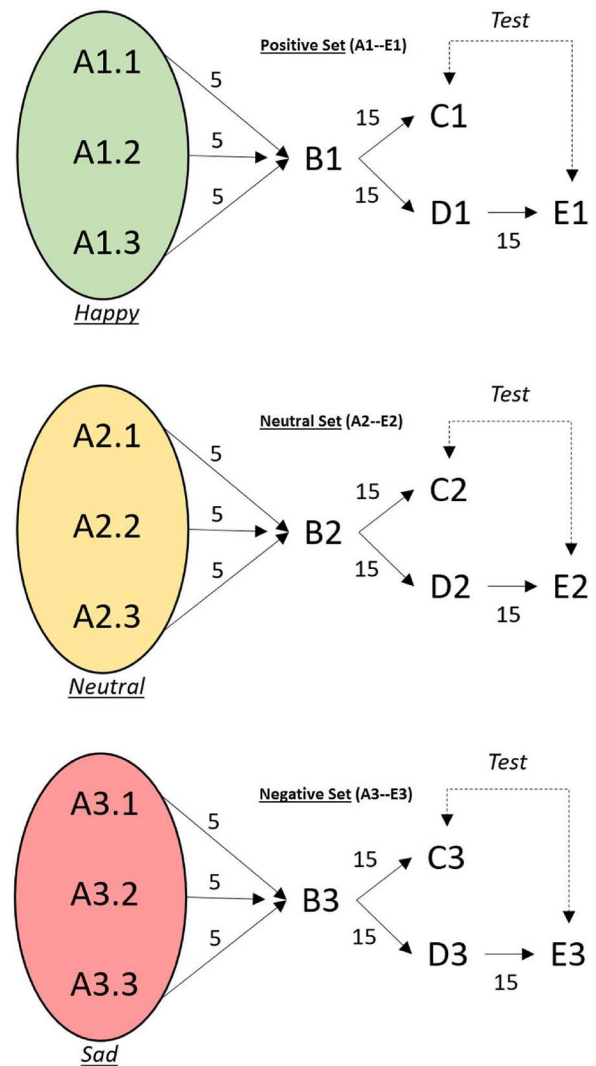


Fig. 1. Illustrates the three 5-member sets established in the present study. The numbers and solid arrows represent the fixed number of training trials for each relation. For example, in the Happy/Positive condition (left), three happy faces (A1.1, A1.2, A1.3) appeared five times each with a nonsense word (B1). B1 also appeared with two other nonsense words, C1 and D1, fifteen times each. The number of training trials were kept constant across the three sets trained. Dashed arrows indicate the transitive relations tested for during the card sorting task. Note that the C and D stimuli were one node away from the emotional face (A) stimuli, where only the C stimuli functioned as end-terms.

reinforcement. Our investigation builds on those findings and asks whether 0-node and  $\geq 1$ -node transfer varies as a function of procedure type (differential reinforcement vs. S-S contiguity), and whether the degree of transfer is positively related to the emergence of transitivity (Dougher et al., 2014). Finally, recall that both C and D stimuli were nodally equidistant from A but where only C served as an end term (since it never served as a sample for subsequent conditional discriminations - Fig. 1). This structure allowed us to test whether end terms across instrumentally conditioned series might be differentially valued due to differences in reinforcement histories (e.g., Green et al., 1993; Wynne, 1995; also see Lazareva et al., 2004). That is, for participants undergoing the MTS, observing significant differences (or not) between post-training ratings for the C and D stimuli would answer whether end terms mitigate transfer effects during human relational learning.

To summarize, our primary goals here were to assess for differences in transitivity and transfer effects between groups exposed to either instrumental (Matching-to-sample, or ‘MTS’) or pairing (Stimulus-Orientation-with-response, or ‘SOresp’) procedures, with four

predictions being made. First, if differential reinforcement facilitates S-S relational learning (Dougher et al., 2014), then the MTS will yield significantly more correct pairs than the SOresp (Hypothesis 1). Second, if differential reinforcement facilitates transfer, participants in the MTS group should produce enhanced transfer effects relative to the SOresp (Hypothesis 2). Third, if reinforcement history significantly effects the emotional saliency of a term, then the ratings for the end-term C stimuli will significantly differ from the D stimuli (Hypothesis 3). Finally, if the emergence of transitivity is positively related to transfer, we predict that those with higher scores on sorting tests will produce more robust transfer (Hypothesis 4). Towards this end, we will parse participants by their transitivity performances post-hoc during analysis. Transfer differences across these re-partitioned groups will test for any relation between transitivity and transfer performances.

## 2. Method

### 2.1. Participants

60 participants ( $23.03 \pm 3.74$  years; 23 females) were recruited from a pool of undergraduate student volunteers and assigned to one of two groups. All participants were right-handed with normal/corrected-to-normal vision with no reported pathologies or drug habits, legal or otherwise. All participants were required to provide written consent prior to participation, and were provided a LACTA® chocolate bar upon completing participation. All procedures described here were approved by the Federal University of São Carlos (UFSCAR) ethics committee.

### 2.2. Apparatus

The SOresp and MTS procedures were designed and implemented on the E-Prime 2 platform (Schneider et al., 2002). Stimuli for pre-training included three images of tools (tool1, tool2, tool3), three of cars (car1, car2, car3), three of fruits (fruit1, fruit2, fruit3), and two abstract geometrical configurations (abstract1, abstract2). Emotion-eliciting stimuli included nine faces consisting of three happy, three neutral and three sad faces, which will collectively be referred to as A1, A2 and A3 respectively for the remainder of the manuscript. Three emotional faces were used to condition a single word since pairings with a single US appear ineffective towards producing transfer (cf., Experiment 1, Gawronski et al., 2015; also see Bortoloti and de Rose, 2009). The remaining 14 stimuli were nonsense words (B1, B2, B3, C1, C2, C3, D1, D2, D3, E1, E2, E3, X1, X2). The faces were selected from the Karolinska Face Database (Lundqvist et al., 1998) based on normative ratings provided by 20 participants from an unrelated study. The tool1, tool3, car1, car3, fruit1, fruit3, C1, C2, C3, E1, E2, X1 and X2 stimuli were each printed on  $3.3 \times 4.7$ " laminated cards for subsequent sorting tests. Valence and arousal ratings were collected using two 100-point visual-analog scales (VAS) developed on the LiveCode® platform. All reported procedures were implemented 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. All data analyses were conducted on IBM's SPSS.

### 2.3. Procedure

Participants were exposed either to a SOresp or a MTS task. All participants first provided valence and arousal ratings for the 14 words and 9 emotional faces as a baseline during a ratings task. Prior to the task, participants were instructed the following (translated from Portuguese)

*"In this task, you will see an image in the center of the screen. Please pay attention to the screen. You will also see two slider scales below the image. Please rate the image along the two scales. On the top scale, please select between SAD and HAPPY. On the bottom scale, please select*

*between EXCITED and CALM. After you have moved the sliders, please press on the button that appears below to go to the next trial. The program will inform you when to call the investigator. Please press the button below to begin."*

The task involved a target stimulus (word/face) presented in the center of the computer screen on a white background, with two VAS scales underneath the image. The first scale was anchored with sad and happy smiley faces on the left and right ends of the scale, representing a SAD-HAPPY (valence) dimension; the second scale was anchored with calm and excited smiley faces on the left and right ends of the scale, representing a CALM-EXCITED (arousal) dimension. The participant was required to move sliders along both scales with the mouse to rate the stimulus. Doing so caused the appearance of a grey button below the scales. Clicking it would turn it green for 200 ms (ms), after which a 800–1000 ms grey inter-trial interval, jittered along 50 ms, would follow. This would be followed by the onset of the next target stimulus. Note that, with each screen, the scales would reset with the sliders at mid-point, and the grey button beneath the scales would be absent. Only when both sliders were moved could participants therefore move to the subsequent trial. Both VAS scales were scored along 100 points, unknown to participants. Note that the sequence of 23 ratings were randomized across time within participants and groups.

After baseline ratings were collected, participants commenced pre-training. This involved participants being presented with fruit1-fruit2, fruit2-fruit3, tool1-tool2, tool2-tool3, car1-car2 and car2-car3 pairs, that were either differentially reinforced (MTS group) or sequentially correlated and oriented towards (SOresp group) across 60 randomly ordered trials. Participants were presented with a shuffled deck of eight cards (fruit1, fruit3, tool1, tool3, car1, car3, abstract1, abstract2) with verbal instructions to sort the cards into pairs. The participant was left alone as s/he formed the pairs, after which s/he would call the experimenter to return. All participants produced the correct transitive pairs during pre-training (i.e., fruit1 → fruit3, tool1 → tool3, car1 → car3, abstract1 → abstract2). Participants then commenced the main training phase along their respective (MTS/SOresp) procedures. This involved each A stimulus (US) paired with its respective B stimulus across a total of 45 training trials (i.e., A1.1/A1.2/A1.3 → B1, A2.1/A2.2/A2.3 → B2, A3.1/A3.2/A3.3 → B3 – see Fig. 1). These were intermixed with training trials involving nine other relations (B1 → C1, B1 → D1, D1 → E1, B2 → C2, B2 → D2, D2 → E2, B3 → C3, B3 → D3, D3 → E3) that were presented 15 times each, yielding 135 more training trials. In total, participants were exposed to 180 trials. The A1 →→ E1, A2 →→ E2 and A3 →→ E3 sets were collectively labelled as Positive, Neutral and Negative sets, respectively, in accordance with the valences of their respective 'A' stimuli. Following completion of the 180 training trials, participants were presented with a deck consisting of C1, C2, C3, E1, E2, E3, X1 and X2 cards alongside the instruction to sort the cards into pairs. Following sorting, participants provided valence and arousal ratings for all stimuli with the ratings task described earlier, marking the end of the experiment. The following sections describe the MTS and SOresp procedures.

#### 2.3.1. MTS (matching-to-sample)

The procedure employed here was based on a MTS format standard to relational learning research (e.g., Bortoloti and de Rose, 2009; Clayton and Hayes, 2004; Kinloch et al., 2013). The MTS commenced with the following instructions (translated from Portuguese)

*"Welcome. In this task, you will first see an image come up on screen. Please click on the image to continue. Next, you will see three images appear on screen. Click on one of these images to continue. The program will inform you whether your responses were correct. Please click on the mouse to begin"*

Pressing the mouse key produced a blank screen with a fixation cross for 500 ms. Next, a sample stimulus would appear in the center of

the screen (e.g., A2), which required that participants orient towards the stimulus and click on it to progress. Clicking on the sample produced a blank inter-stimulus interval (ISI) of 500–1500 ms with a 50 ms jitter. Next, three comparison stimuli (e.g., B1, B2, B3) would appear along three randomly selected corners of the screen. Participants had to orient towards and click on a specific comparison to continue. This would be followed by the word “Correct” if the sample → comparison discrimination was correct (e.g., A2 → B2B1B3), or by a red X if the sample → comparison discrimination was wrong (e.g., A2 → B2B1B3). The feedback message remained for 1500 ms, followed by a blank inter-trial interval (ITI) of 3000 ms ITI, signalling the end of one trial. Each MTS trial required at least two orienting responses and involved differential reinforcement of S-S relations.

2.3.2. SOresp (stimulus-orientation-with-response)

The SOresp instructions were left unchanged from our previous iteration (p. 59). Participants undergoing the SOresp first viewed a fixation cross that randomly appeared in the center of one of four screen quadrants. The task required moving the mouse pointer to the cross and clicking on it to continue (p. 59). Clicking on the cross caused it to be replaced by a stimulus in the same location for 1500 ms. This was followed by a blank screen with a ISI of 500 to 1500 ms with a 50 ms jitter. A second stimulus then appeared in the same quadrant for 1500 ms. This was followed by a 3000 ms blank ITI, marking the end of one trial. The SOresp procedurally reinforced a single orienting response with trial progression as a consequence, but did not differentially reinforce specific S-S sequences.

3. Results

3.1. Differential reinforcement and transitivity

60 participants produced four card pairs each from a deck containing C1, C2, C3, E1, E2, E3, X1 and X2. Individuals could produce between 0 and 3 correct pairs for a maximum of 90 correct pairs per group. Pairs deemed correct were C1-E1, C2-E2 and C3-E3. During the sorting tests, the SOresp and MTS groups produced 54/90 (60.7%) and 35/90 (38.8%) correct pairs, respectively (Table 1). The 22% difference in proportions was significant,  $\chi^2(1) = 8.023, p = .005$ . Group was significantly associated with the number of correct pairs produced, as determined by Fisher’s exact test,  $p = .004$  (1-tailed). These results suggest differential reinforcement of S-S relations did not enhance transitivity yields relative to the sequential pairing procedure, countering Hypothesis 1. For the MTS group, the proportion of correct responses produced during training (Table 2) was positively and non-significantly correlated with the number of correct pairs produced during sorting (Kendall’s Tau = .23;  $p = .16$ ).

Table 1  
Correct pairs produced following sorting.

Group	Transitivity	n <sup>a</sup>	Correct <sup>b</sup>
SOresp	0	4	0
	1	7	7
	2	11	23
	3	8	24
	Total	30	54
MTS	0	9	0
	1	10	10
	2	8	16
	3	3	9
	Total	30	35

<sup>a</sup> Number of participants in each condition.  
<sup>b</sup> Total number of correct pairs recorded for each Transitivity condition.

Table 2  
Correct discriminations during training (MTS group only).

Trans <sup>a</sup>	A-B (45)	B-C (45)	C-D (45)	D-E (45)	Cr <sup>b</sup>	%	%Group <sup>c</sup>
3	42	42	40	39	163	90.6	
3	38	41	40	38	157	87.2	For n = 3
3	40	39	41	36	156	86.7	88.2%
2	39	41	40	34	154	85.6	
2	37	35	38	32	142	78.9	
2	41	40	41	29	151	83.9	
2	41	41	39	30	151	83.9	
2	40	40	41	35	156	86.7	
2	40	40	38	39	157	87.2	
2	41	40	37	38	156	86.7	For n = 8
2	40	41	32	31	144	80	84.1%
1	40	39	38	38	155	86.1	
1	41	41	40	31	153	85	
1	39	38	28	36	141	78.3	
1	38	32	39	31	140	77.8	
1	40	40	27	35	142	78.9	
1	41	41	40	39	161	89.4	
1	42	38	39	34	153	85	
1	40	40	35	25	140	77.8	
1	41	37	40	41	159	88.3	For n = 10
1	42	40	34	39	155	86.1	83.3%
0	40	40	37	36	153	85	
0	42	41	39	40	162	90	
0	41	37	36	28	142	78.9	
0	42	37	33	39	151	83.9	
0	41	34	38	30	143	79.4	
0	42	41	38	40	161	89.4	
0	41	32	36	32	141	78.3	
0	41	39	39	35	154	85.6	For n = 9
0	42	31	34	33	140	77.8	83.1%

<sup>a</sup> Number of correct pairs produced during training, ranging from 0 to 3.  
<sup>b</sup> Correct responses recorded out of 180 total responses made and their corresponding percentages.  
<sup>c</sup> Correct response percentage by sorting performances.

3.1.1. Differential reinforcement and transfer (Valence)

The valence and arousal ratings collected for all stimuli before (baseline) and after (post) relational training is presented in Fig. 2. Valence ratings collected before and after relational training/testing were subjected to mixed between-within analyses of variance (ANOVAs), with group (SOresp × MTS) and stimulus as the between-subjects factors and time (baseline × post) as a within-subjects factor. The levels of the stimulus factor were contingent on nodal distance, and have been provided in corresponding segments below.

**0-node (A → B):** A 2 × 2 × 3 ANOVA, with B1, B2 and B3 as three levels of the stimulus factor was run. There was homogeneity of variances for the baseline ( $p = .556$ ), but not post ( $p = .018$ ), ratings for the B stimuli as assessed by Levene’s test. Note that Mauchly’s sphericity test was violated ( $p < .001$ ) for all conditions, hence all reported *F* values were Greenhouse-Geisser corrected. A significant three-way interaction was found between stimuli (B1 × B2 × B3), group (SOresp × MTS) and time (baseline × post),  $F(2, 174) = 5.808, p = .004$ , partial  $\eta^2 = .063$ . Time interacted significantly with the B stimuli,  $F(2, 174) = 43.95, p = .001$ , partial  $\eta^2 = .336$ , indicating 0-node transfer had occurred. There was no significant interaction between group and time,  $F(2, 174) = .035, p = .851$ . There was no significant main effect for group across the stimulus levels during baseline,  $F(5, 174) = .772, p = .464$ . A significant main effect appeared only after relational training,  $F(5, 174) = 38.388, p < .001$ . Pairwise comparisons revealed only B3 to be significantly different ( $p = .003$ ) between groups after training.

**1-node (A → C, A → D):** A 2 × 2 × 6 ANOVA, with C1, C2, C3, D1, D2 and D3 (Fig. 1) as six levels of the stimulus factor was run. There was homogeneity of variances for both C and D stimuli before



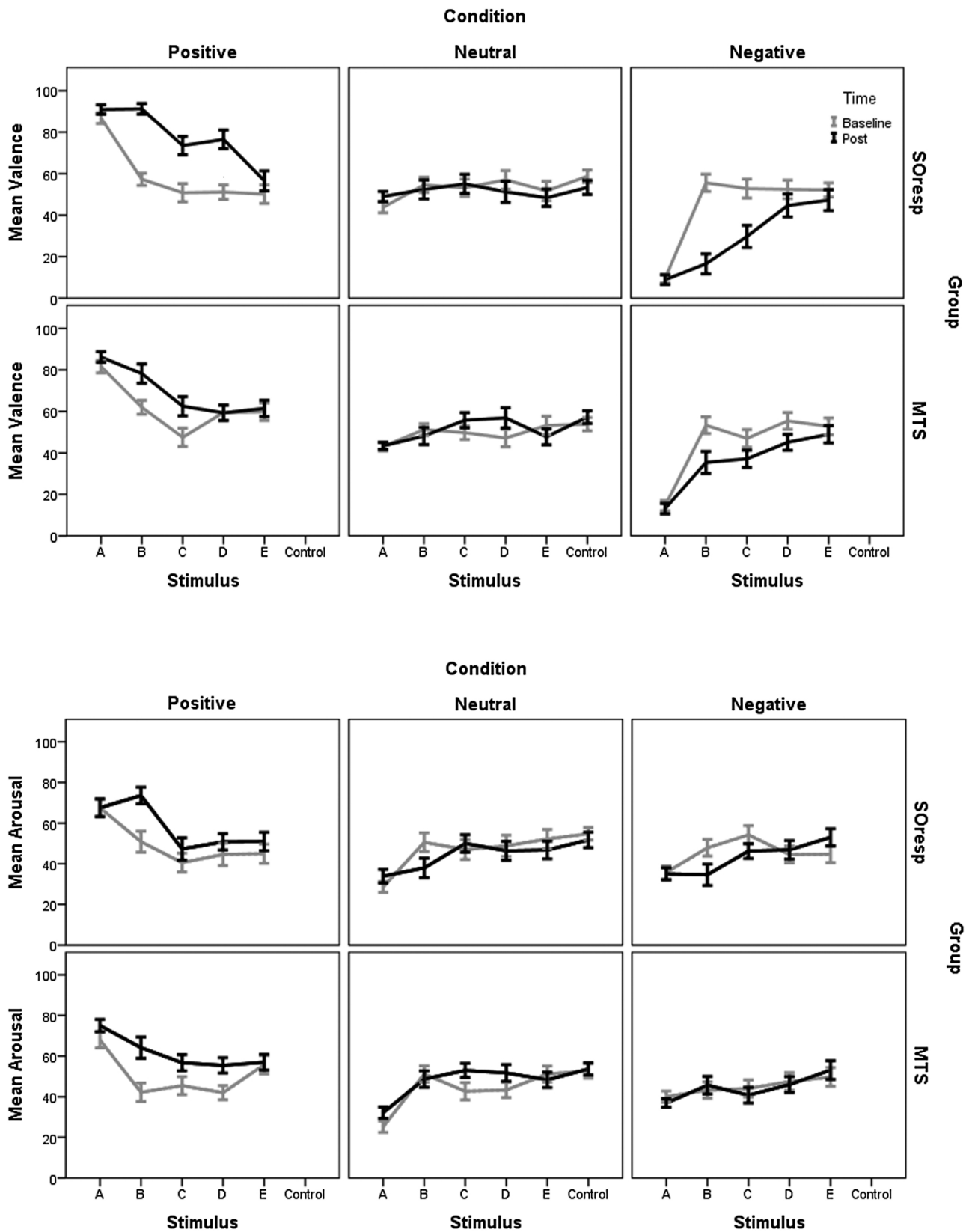


Fig. 2. Mean valence (top two rows) and arousal (bottom two rows) ratings for the SOresp and MTS groups (right column). Grey and black traces indicate mean ratings collected before (baseline) and after (post) relational training respectively. Ratings along the y-axis range from 0-to-100, illustrating SAD-to-HAPPY (valence) and CALM-to-EXCITED (arousal) dimensions. Error bars indicate 1\*SEM. The x-axis illustrates stimulus categories within a condition, where positive, neutral and negative sets included the A1-B1-C1-D1-E1, A2-B2-C2-D2-E2 and A3-B3-C3-D3-E3 stimuli respectively. Recall that stimuli A were emotional faces, and stimuli B-E were nonsense words. Controls included nonsense words that were not used during training tasks - these did not significantly vary between ratings for any of the groups.

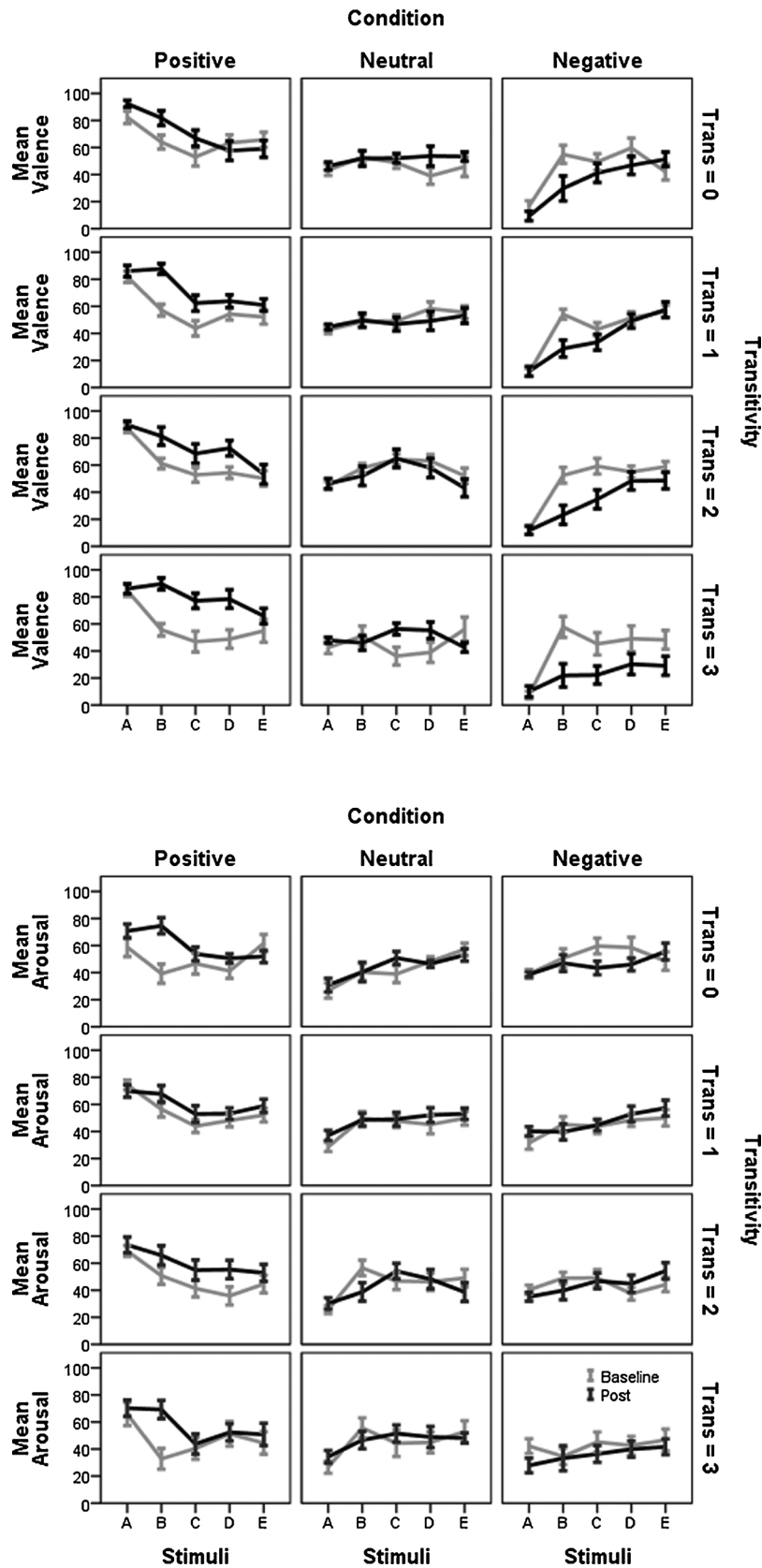


Fig. 3. Mean valence (first four rows) and arousal (bottom four rows) ratings before and after relational training (x-axis), parsed by number of correct transitive pairs produced during sorting tests (between 0 and 3). Error bars indicate SEM. Ratings were combined across the MTS and SOresp groups. The number of participants in the Trans = 0, Trans = 1, Trans = 2 and Trans = 3 conditions were 13, 17, 39 and 33 respectively (see Table 1).

( $p = .917$ ) and after ( $p = .194$ ) relational training. A significant three-way interaction was found between the six stimuli, group and time,  $F(5, 348) = 2.93, p = .013$ , partial  $\eta^2 = .04$ . Time significantly interacted with stimuli,  $F(5, 348) = 8.793, p < .001$ , partial  $\eta^2 = .112$ , indicating 1-node transfer. The interaction between time and group was not significant,  $F(5, 348) = .02, p = .889$ . A significant main effect for group across the stimulus levels was found only after relational training,  $F(5, 348) = 8.932, p < .001$ , not before ( $p = .538$ ). Pairwise contrasts between groups revealed that only D1 was rated as significantly higher ( $p = .008$ ) by the SOresp group relative to the MTS group.

**2-node (A → E):** A  $2 \times 2 \times 3$  ANOVA, with E1, E2 and E3 (Fig. 1) as three levels of the stimulus factor. There was homogeneity of variances for baseline ( $p = .760$ ) and post ( $p = .682$ ) ratings for the E stimuli as assessed by Levene's test. The three-way interaction between stimuli (E1  $\times$  E2  $\times$  E3), group and time was not significant,  $F(2, 174) = .115, p = .892$ . Two-way interactions were not significant between group and time ( $p = .694$ ), or between stimulus and time ( $p = .284$ ). Our analyses provide no statistically significant evidence for 2-node transfer, although visual inspection of the ratings trends observed for the E stimuli suggests otherwise.

### 3.1.2. Differential reinforcement and transfer (Arousal)

Arousal ratings collected before and after relational training/testing were subjected to a similar assortment of mixed-model ANOVAs as above, with group and stimulus as between-subjects factors and time as a within-subjects factor. Levels of the stimulus factor were contingent on nodal distance.

**0-node (A → B):** A  $2 \times 2 \times 3$  ANOVA, with B1, B2 and B3 as three levels of the stimulus factor was run. There was homogeneity of variances for baseline ( $p = .769$ ) and post ( $p = .282$ ) ratings. The three-way interaction between stimuli, group and time was not significant,  $F(2, 174) = .935, p = .395$ . The B stimuli significantly interacted with time,  $F(2, 174) = 14.647, p < .001$ , indicating 0-node transfer. No significant interaction appeared between group and time ( $p = .098$ ). There was no significant main effect for group across the stimulus levels during baseline,  $F(5, 174) = .822, p = .535$ . A significant main effect appeared after relational training only,  $F(5, 174) = 10.646, p < .001$ . Pairwise comparisons between groups were not significant for any of the B stimuli after training (all  $p$ 's  $> .09$ ).

**1-node (A → C, A → D):** A  $2 \times 2 \times 6$  ANOVA, with C1, C2, C3, D1, D2 and D3 as six levels of the stimulus factor revealed a non-significant three-way interaction between group, time and stimulus,  $F(5, 348) = .316, p = .903$ . There was homogeneity of variances for baseline ( $p = .734$ ) and post ( $p = .511$ ) ratings. Time significantly interacted with stimulus,  $F(5, 348) = 1.792, p = .025$ , indicating 1-node transfer. Stimulus and group did not significantly interact ( $p = .153$ ). Pairwise comparisons between groups were not significant for any of the stimuli after training (all  $p$ 's  $> .8$ ).

**2-node (A → E):** A  $2 \times 2 \times 3$  ANOVA, with E1, E2 and E3 as three levels of the stimulus factor revealed a non-significant three-way interaction,  $F(2, 174) = .249, p = .78$ . Time did not significantly interact with group ( $p = .63$ ) or stimulus ( $p = .234$ ). All pairwise contrasts were non-significant (all  $p$ 's  $> .9$ ). The combined results suggest that 0-node and 1-node transfer appeared for valence and arousal for both groups, with a more robust effect by the SOresp group (Fig. 2). No statistical evidence was found for transfer for the E stimuli, which were 2 nodes apart from the A stimuli (Fig. 1). Our results indicate that differential reinforcement did not enhance transfer – indeed, visual inspection of Fig. 2 suggests the opposite effect, countering Hypothesis 2.

### 3.2. End-terms and transfer (MTS only)

Differences in post-measurement valence and arousal ratings when contrasting C1 with D1, and C3 with D3, were non-significant (all  $p$ 's  $> .5$ ). The lack of significant differences across the C1 vs. D1 and

C3 vs. D3 contrasts suggest that reinforcement histories did not significantly influence the emotional saliency of end terms, contra Hypothesis 3. Exploratory analyses across members of the SOresp group yielded similarly non-significant differences along valence and arousal for the C1 vs. D1 and C3 vs. D3 contrasts (all  $p$ 's  $> .3$ ).

### 3.3. Relation between transfer and transitivity

To determine whether transfer effects were related with transitivity performances, participants from both groups were re-partitioned into four categories based on their sorting performances (see Fig. 3 and Table 1). We ran four  $6 \times 2$  multivariate analyses of variance (MANOVAs) with stimuli (6) and time (2) as factors with valence and arousal ratings as dependent measures: a significant interaction between the two factors towards valence and/or arousal was deemed the threshold for transfer. The baseline and post-measurement ratings across the re-partitioned groups are presented in Fig. 3.

For the 13 participants who did not produce any accurate pairs during sorting (*Transitivity* = 0), stimuli and time did not significantly interact towards valence ( $p = .222$ ) or arousal ( $p = .093$ ). For the 17 participants who produced one correct pair during sorting (*Transitivity* = 1), no significant interactions appeared for valence ( $p = .103$ ) or arousal ( $p = .982$ ). For the 39 participants who produced two correct pairs (*Transitivity* = 2), time and stimuli significantly interacted for valence,  $F(5, 204) = 4.860, p < .001$ , Wilks'  $\Lambda = .889$ , partial  $\eta^2 = .057$ , but not arousal ( $p = .363$ ). For the remaining 33 participants who produced all the correct pairs (*Transitivity* = 3), time and stimuli interacted significantly for valence,  $F(5, 132) = 4.243, p = .001$ , Wilks'  $\Lambda = .841$ , partial  $\eta^2 = .083$ , not arousal ( $p = .977$ ). Significant interactions between stimulus valences and time of measurement for participants who produced at least two correct pairs during the sorting tests (*Transitivity* = 2, *Transitivity* = 3), but not for those who produced 1 or 0 correct pairs (*Transitivity* = 0, *Transitivity* = 1) suggests that transfer magnitude may be positively related to the emergence of transitive relations, supporting Hypothesis 4.

## 4. Discussion

Participants underwent either an instrumental matching-to-sample (MTS) or a Pavlovian stimulus-pairing (SOresp) procedure for establishing three 5-member stimulus sets, structured in the order of A → B, B → C, B → D, and D → E, where all 'A' stimuli were emotional faces and all remaining stimuli were nonsense words (Fig. 1). Our goal was to determine whether the emergence of transitive stimulus control, as measured by card sorting, and transfer, as measured by self-reported valence and arousal ratings, differed following exposure to either of the two procedures. Across sorting tests, participants in the SOresp group produced significantly more correct pairs than those in the MTS group, supporting the claim that environmental S-S correlations are more fundamental towards learning of S-S relations relative to differential reinforcement of S-S relations (Avellaneda et al., 2016; Tonneau, 1993, 2001).

Self-reported valence and arousal ratings for the words associated with happy and sad faces differed, in many cases significantly, before and after relational learning across both groups, illustrating transfer (Fig. 2). Transfer magnitude was positively related with yields of transitivity (Fig. 3). Specifically, transfer occurred for the B, C and D stimuli, which were 0 and 1 nodes away from the unconditioned face (A) stimuli, but not for E stimuli which were 2 nodes away. Our data are consistent with the notion that "transfer arises from stimulus correlations...independently of...matching equivalence (emphasis added)" (Tonneau, 2001, p.18). We add to this claim by highlighting the facilitative role orienting plays in Pavlovian relational learning (Maltzman, 1979; Joshi et al., 2017; Pavlov, 2010; Sokolov, 1990). A final point of note is the lack of significant differences ratings for the C1 vs. D1 and

C3 vs. D3 contrasts for those who underwent MTS training, indicating that the emotional saliency of end-terms is not significantly determined by differences in reinforcement received, or at least when the tested items are nodally equidistant from the emotionally salient stimulus (Fields et al., 1984).

In sum, we replicated Amd's (2017) results while expanding upon those findings in at least three significant ways. First, the SOresp produced greater transitivity than the MTS even as the size of the trained sets increased to five members. Second, those undergoing SOresp training produced 0-node and 1-node transfer at levels similar to, and sometimes greater than, those who underwent MTS training. Finally, the end-terms within a relational series did not significantly mitigate the self-reported emotional saliency of those terms.

One reason behind the differences in the outcomes reported here versus those reported in some earlier works (e.g., Clayton and Hayes, 2004; Kinloch et al., 2013) may be that our SOresp procedure minimizes the influence of stimulus/associative competition (e.g., Burton et al., 2017; Matute and Pineño, 1998). Assuming that i) increasing the number of potentially-meaningful instances to be discriminated from increases with the number of stimuli competing for discriminative control (Leader and Barnes-Holmes, 2001, p.441), and that ii) discriminable stimuli presented simultaneously can compound to block the formation of relations between those stimuli independently (Markham and Dougher, 1993; Rehfeldt et al., 1998) and, finally, that iii) orientation is necessary for highlighting *what* to discriminate during Pavlovian learning (Pavlov, 2010), it readily follows that an orientation-pairing (SOresp) procedure involving sequences of individual stimulus items will yield more transitive relations than a differential-reinforcement (MTS) procedure since the latter presents a greater number of comparisons, equating to increased associative competition (also see Experiments 3 and 4, Leader and Barnes-Holmes, 2001). We argue that the lack of an orientation requirement coupled with associative competition effects played a significant role in previous reports where pairing procedures under-performed relative to the MTS in terms of emergent transitivity (e.g., Clayton and Hayes, 2004; Kinloch et al., 2013). Our SOresp further highlights how orienting towards stimulus-stimulus pairs that are presented sequentially (as opposed to simultaneously – cf., Stahl and Heycke, 2016) facilitates the emergence of transitive relations and transfer effects. A future work could manipulate the SOresp so as to elicit orientation without an explicit response requirement, perhaps through manipulating the luminance of the respective quadrants in the SOresp and tracking gaze, determining if orienting *prima facie* is the critical variable determining contiguous S-S relations.

We conclude with some potential limitations of the present study. First, note that all participants here were required to form pairs from a deck with six stimulus cards (C1, E1, C2, E2, C3, E3) and two distractor cards (X1, X2) during the sorting tests. Although the intent for including the distractors were to determine more conclusively the number of transitive relations formed relative to our earlier study, the fact that X1 and X2 were never displayed during training may have caused them to be linked together via exclusion (e.g., De Rose et al., 1996; McIlvane et al., 1987). That is, even if we were to increase the number of distractors to the *n*th order, the fact that such stimuli never appeared during training would constitute the very reason as to why they would be predicted to be paired together. Future investigations into the effectivity of sorting tests for transitivity could attempt to include additional distractor stimuli as alternative comparisons that can be linked independently of the target stimulus sets in order to control for matching through exclusion (again, see de Rose et al., 1996). Second, while the SOresp here did not provide any possibility of forming erroneous S-S links, since all the paired stimuli corresponded with the desired relational structure (e.g., D1 was always followed by E1 during SOresp training), this was not the case for participants undergoing the MTS. Specifically, the percentages of correct responses recorded ranged from 77.8% to 90.6% across participants (Table 2), indicating that

negative stimulus control may have effected the MTS group's performances to different degrees (Johnson and Sidman, 1993). The total number of correct responses did not appear to be significantly related to transitive performances, although a trend could be noted (Table 2). A future replication could first run a MTS and yoke the number of SOresp trials to the median number of incorrect trials in the former to corroborate whether the present results hold.

A final limitation, common to most published investigations of transfer within contemporary behavioristic literature, is not considering the influence of subliminal/associative versus aware/propositional influences on transfer (cf., Gawronski et al., 2017). Given that 0-node transfer has been well-documented with procedures hypothesized to incorporate primarily associative processes (Heycke et al., 2017), an important next step is to determine whether  $\geq 1$ -node transfer can be documented without awareness. Evidence, or a lack thereof, of transfer across associatively (vs. propositionally) linked stimuli can inform us as to how important explicitly elaborated propositions are for demonstrations of transfer. Future researchers could attempt to establish series of subliminally linked stimuli and explore the extent to which the present transfer effects can be replicated. This could be done, for instance, by reducing the duration that individual stimuli appear from 1500 ms, as was the case presently, to 30 ms, as was the case in Stahl et al., (2016). One could further incorporate electrophysiological measures known to reliably track transfer over short time scales, including early event-related components (e.g., Amd et al., 2013) and oscillatory alpha activity (Amd and Roche, 2016). Given the abundance of evidence highlighting the roles both associative and propositional processes pose in human learning (cf., Trobalon and Chamizo, 2016), any valuable behavioristic model of transfer must account for the influence of these processes before attempting to prematurely explain 'all' language.

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