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The Impact of Arbitrarily Applicable Relational Responding on Evaluative Learning About Hypothetical Money and Shock Outcomes

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Abstract

Evaluative learning comprises changes in preferences after co-occurrences between conditioned stimuli (CSs) and an unconditioned stimulus (US) of affective value. Such co-occurrences may involve relational responding. Two experiments were conducted on the impact of arbitrary relational responding on evaluative preferences for hypothetical money and shock outcomes. In Experiment 1, participants were trained to make arbitrary relational responses by placing CSs of the same size but different colours (A, B and C) into boxes according to the following instructions: "B is bigger than A" and "C is bigger than B". They were then instructed that these CSs represented different intensities of hypothetical USs (money or shock). Results showed that liking ratings of the CSs were altered in accordance with the underlying bigger than or smaller than relations. A reversal of preference was also observed such that the CS associated with the smallest hypothetical shock was rated more positively than the CS associated with the smallest amount of hypothetical money. In Experiment 2, we employed training and testing procedures from Relational Frame Theory (RFT) to establish a relational network of comparative (more than/less than) relations consisting of five CSs (A-B-C-D-E). Overall, evaluative preferences were altered, but not reversed, depending on (a) how stimuli had been related to one another during the learning phase and (b) whether those stimuli referred to money or shocks. The use of RFT as a framework to study relational learning effects in evaluative learning is discussed.

Keywords: relational responding, arbitrary stimulus relations, more than and less than, evaluative learning, reversal.

In evaluative learning, a change in the liking of a conditioned stimulus (CS) occurs after its co-occurrence with an unconditioned stimulus (US) of affective value (Gast, Gawronski, & De Houwer, 2012; Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010; Levey & Martin, 1975). An emerging view of such learning is that it may depend on the formation and evaluation of relations between the particular stimuli (Mitchell, De Houwer, & Lovibond, 2009). For instance, Peters and Gawronski (2011) presented participants with four neutral faces as CSs and either positive or negative valenced behavioural descriptions as USs. The task was to guess the accuracy of each statement via corrective feedback. Participants were also instructed that when a behavioural description turned out to be false, they should assume the opposite evaluation was true. This created four categories of targets and evaluations based on the information provided: (1) targets based on positive, accurate descriptions, (2) targets based on negative, accurate descriptions, (3) targets based on positive, inaccurate descriptions, and (4) targets based on negative, inaccurate descriptions. Peters and Gawronski subsequently found that participants' implicit and explicit evaluations were in line with the instructed relation between the faces and statements that were held to be either valid (true) or invalid (false), with the positive-true CS and negative-false CS rated more positively than the positive-false CS and negative-true CS. Further studies have replicated and extended this basic relational effect (e.g., Gast & De Houwer, 2012; Zanon, De Houwer, & Gast, 2012; Zanon, De Houwer, Gast, & Tucker Smith, 2014).

Propositional accounts of evaluative learning contend that the relation between the stimuli predominates over stimulus pairings on the subsequent measures of liking (De Houwer, 2007, 2009; Hughes, Barnes-Holmes, & De Houwer, 2011; Mitchell et al., 2009). According to this view, propositions are "statements about the world that can be either valid or invalid" (Zanon et al., 2014, p. 2107) and which, in the context of evaluative learning, may include relational information about whether or not stimuli are related and precisely in what way (e.g., A *causes* B, A is *the same as* B, etc.). In the present study, we sought to investigate further relational influences over evaluative learning in ways predicted by a functional account of language and cognition: relational frame theory (RFT; Dymond & Roche, 2013; Stewart, 2016). The central idea of RFT is based on the principle of relational responding that refers to the ability to respond to relations between stimuli rather than just responding to each stimulus separately. Therefore, RFT may appear to be a good candidate to investigate further the role of relational responding in evaluative learning.

Within this general perspective, a fundamental theoretical question arises concerning how relations between the CSs and USs should be characterized and it is in this regard that RFT may be informative for evaluative learning (Dymond & Roche, 2013; Hayes, 1994; Hayes, Barnes-Holmes, & Roche, 2001; Hughes, De Houwer, & Perugini, 2016). The concept of stimulus relations is a hallmark of RFT (Hayes, 1994; Hayes et al., 2001; Stewart, 2016), and RFT's main tenets of arbitrarily applicable relational responding can be summarized as follows: (1) *Mutual entailment* implies that relations between stimuli are bidirectional. Responding to the relation in one direction (A related to B) entails responding to the relation in the other direction (B related to A) (see Arcediano & Miller, 2002); (2) *Combinatorial entailment* implies that two or more stimulus relations can mutually combine. Responding to two combined relations (between A and B and between C and B) can entail a response to a third relation (between A and C) (see also, Barnet and Miller, 1996); (3) The third tenet, *transformation of stimulus functions* explains that the functions of a stimulus (for example, such as liking or disliking something) can be altered or transformed on the basis of its relation to other stimuli (Dymond & Rehfeldt, 2000). RFT's emphasis on relational responding is critical for evaluative learning because it allows specific predictions to be made about the outcomes of patterns of transformation determined by the relations that obtain between the particular stimuli involved (Dymond & Roche, 2013; Hayes et al., 2001; Stewart & McElwee, 2009).

Molet, Macquet and Charley (2013) trained participants on a relational responding procedure embedded within a novel evaluative learning paradigm in order to explore the ways in which stimuli are related potentially influencing evaluative ratings. The participants were trained to order various stimuli in boxes by size (i.e., three CSs of small, medium, and large sizes). By dragging the various stimuli into the boxes, they were making a relational response: responding to the stimuli based on the relations (in terms of size) that obtained among them. Molet et al. (2013) considered each act of putting a set of stimuli in the boxes a relational response. After this, participants learned via standard evaluative learning procedures that some stimuli represented levels of hypothetical electric shock and other different stimuli represented different hypothetical amounts of money. Results showed (1) an effect of evaluative learning, with generally more positive evaluations of CSs representing positive rather than negative USs; (2) a CS-US intensity effect, with larger conditioning effects for CSs representing USs of more intense relational value; and (3), a reversal in evaluative learning effects for the relationally weakest CS-US combinations (i.e., more positive evaluations of CSs associated with USs representing a mild shock than a small amount of money).

In Molet et al. (2013), the relations were partly determined by physical cues (i.e., the size of the CSs), which were related in an arbitrarily applicable manner via the instructions given to participants about how to sort the CSs based on the non-arbitrary property of size (see, Stewart, Barrett, McHugh, Barnes-Holmes, & O'Hora, 2013). It is possible that participants' ratings may have been partly influenced by the non-arbitrary property of size. That is, the largest sized CS may have prompted higher ratings than the next closest in size CS simply because it was larger. It is necessary therefore to separate out the influence of the size of the CSs from the arbitrary relations established via instruction if we are to further understand the role of relational responding in evaluative learning. This was the motivation for Experiment 1. It is also noteworthy that arbitrary relational learning is a key feature of language and cognition and is a core component of RFT (Gross & Fox 2009). According to RFT, relations are called *arbitrary* because they are based on, and capable of modification via, social convention rather than defined via their physical properties. Features of the environment or "contextual cues", such as phrases like "is bigger than", then become discriminative for certain types of relational responding. That is, the function of contextual cues is to specify what forms of arbitrarily applicable relational responses are brought to bear on the particular relational stimuli involved (Hayes et al., 2001). Finally, and most importantly, in order to show that RFT is a good candidate to study relational learning effects in evaluative learning, it seems critical to test its main tenets as discussed earlier (i.e., mutual and combinatorial entailment and transformation of stimulus functions). This was the goal for Experiment 2.

In Experiment 1, participants were exposed to a relational training procedure consisting of three arbitrary stimuli of different colours (A, B, C) that represented either hypothetical levels of electric shock or sums of money. Participants were instructed that, "B is bigger than A" and "C is bigger than B". The objective of Experiment 1 was, therefore, to investigate whether arbitrary relational responding would modulate evaluative ratings of A more than B more than C (A>B>C) and A less than B less than C (A<B<C). Experiment 2 further investigated this possibility with arbitrarily applicable relational training and testing procedures from RFT by creating a 5-series network (A-B-C-D-E), in order to test for mutual and combinatorial entailment, and to examine transformation of participants' evaluative choices and ratings of cues related to hypothetical money and shock USs.

Experiment 1

Method

Participants

Twenty-four participants (12 men) aged between 18 and 23 years old (M_{age} = 20.69, *SD* = 2.17) from the University of Lille were randomly allocated to one of the two groups: Money and Shock (*n*=12 in each group). A previous meta-analysis (Hofmann et al., 2010) reported a medium effect size for evaluative learning (d = 0.52). To determine sample size, an a priori power calculation revealed that with such an effect size, alpha set to 0.05 (two-tailed), and power set to 0.8, a sample size of 12 per group would be required. Moreover, the sizeable effect (η^2_p = .76) of the reversal of CS evaluations for the CS-US pairings of the least intense relational value (i.e., CSs were evaluated more positively in the context of small CS/US- than small CS/US+ associations) that we calculated from data reported in Experiment 1 of Molet et al. (2013) indicates that our sample size is adequate.

Apparatus

Participants performed the experiment using a Dell™ Latitude™ E540 computer. The procedure was programmed using Visual Basic®. Three blue, purple and orange circles and three blue, purple and orange triangle figures of the same size were used as CSs (A, B, and C). The colour codes were counterbalanced across groups and participants. Three boxes were used to place the CSs. One image of a lightning bolt was used to represent electric shock, the negative US, and one image of a stack of Euro (€) was used as the positive US. All stimuli were counterbalanced across participants. The 9-point portrait version of the Self-Assessment Manikin (SAM) scale for valence (Bradley & Lang, 1994) was used to measure evaluative ratings. The SAM portraits ranged from a smiling, happy figure to a frowning, unhappy figure.

Procedure

Participants were run individually in sessions of approximately 20 minutes duration. Experiment 1 involved two phases: a learning phase that consisted of a minimum of four training trials and a testing phase that assessed evaluative choices and ratings of the CSs. Training and testing trials were presented in sequential pairs; the training part was repeated, if necessary, prior to the testing trials.

For both groups, the training trials consisted of ordering CSs into boxes. At the beginning of each training trial, participants received instructions that allowed them to place the CSs into correct boxes: “B is bigger than A” and “C is bigger than B”. By placing the CSs into the correct boxes, they made an arbitrary relational response to the CSs. That is, they responded to the stimuli based on the colour-size coded relations. Half of the participants were trained to put the CSs in order of size from smallest to biggest, whereas the remaining participants were trained to put the CSs in the boxes in the reverse order of size (i.e., from biggest to smallest). To put a CS into a box, the participant had to click on it and then click on the box of her/his choice. If the participant correctly ordered the CSs in the boxes, the word “correct” appeared. If the participant incorrectly ordered the CSs in the boxes, the word “incorrect” appeared and the first part of the training trial was repeated until participants responded correctly (i.e., placing the colour CSs in the three boxes in the correct order specified by the instructed relation). The feedback message remained visible for 1 s. After a successful trial, the CSs placed into the correct boxes stayed on screen and new instructions for the second part were displayed.

Participants then proceeded to the evaluative testing trials. Half of the participants were trained to relate CSs with imaginary Money (Group Money) and the remaining participants were trained to associate CSs with imaginary Shock (Group Shock) (a pilot study revealed that a within-subject design made it difficult to train and test the requisite relations on a brief timescale). Participants in Group Money were instructed to “imagine that the CSs represented different amounts of money" (an image of a stack of Euro notes was displayed below the boxes); whereas the participants in Group Shock were told to "imagine that the CSs represented different levels of electric shock" (an image of a lightning bolt was displayed below the boxes). The instructions remained visible for 5 s. In both groups, the participants were then asked to answer two successive questions (displayed at the top of the computer screen): "Which would you most like to receive?" and "Which would you least like to receive?" (counterbalanced). To make a choice, participants had to click on the choice button located below each CS. These choices were not recorded. However, participants then expressed their immediate emotion for each CS successively presented in random order using the SAM scale for valence. These data were recorded in the testing phase and constituted our primary dependent measure in this experiment. Overall, CSs were constant in size but differed in colour (A, B, and C). Participants were instructed to respond to the CSs based on the following instructed relations: "B is bigger than A" and "C is bigger than B". By putting the stimuli into the boxes, participants were making an arbitrary relational response (i.e., responding to the stimuli based on the relations in terms of colour-size cues). For example, when participants placed stimulus A to the left of stimulus B, they were responding to the relation that A is smaller than B and B is bigger than A. Consider that A is to the left of C, then the relation between A and C can be seen as a combination of the other relations. To put A and C in the right order, participants did not even need to directly compare them to each other. The comparison of each to B is sufficient. That is, participants could have combined the relations each has to B. In other words, by responding to the relation between A and B (putting A to the left of B) and by responding to the relation between C and B (putting B to the left of C), participants may also be responding to the combined relation between A and C (because A would already be to the left of C). The upper part of Figure 1 depicts these relations.

Insert Figure 1 About Here

Results and Discussion

The evaluative ratings of the CSs for both groups are shown in Figure 1 (lower panel). A 3 (CS size: A, B, C) x 2 (US valence: Money and Shock) ANOVA with repeated measures on CS size performed on the evaluative ratings of the CSs revealed a main effect of US valence, $F(1, 22)= 10.67$, $p<.01$, $MSE = 4.52$. The CS size x US valence interaction was also significant, $F(2, 44)= 45.97$, $p<.001$, $MSE = 1.68$. Planned comparisons for ratings involving Money ($_{\text{Money}}$) and Shock ($_{\text{Shock}}$) using the appropriate error terms pooled from the overall analysis found that C_{Money} was rated more positively than B_{Money}, $F(1,11) = 10.56$, $p < .01$, and B_{Money} than A_{Money}, $F(1,11) = 6.25$, $p < .03$. In contrast, C_{Shock} was rated more negatively than B_{Shock}, $F(1,11) = 22.39$, $p < .001$, and B_{Shock} than A_{Shock}, $F(1,11) = 17.74$, $p < .01$.

Interestingly, A_{Shock} was evaluated more positively than A_{Money}, $F(1,22) = 5.26$, $p < .04$, whereas B_{Shock} was rated more negatively than B_{Money}, and C_{Shock} than $C_{Money,}$ $Fs(1,22) = 10.22$ and 59.28, p's < .01 and .001, respectively. This reversal of preference, such that the CS paired with the smallest hypothetical shock (A_{Shock}) was rated more positively than the CS paired with the smallest amount of hypothetical money (A_{Money}), replicated our earlier findings (Molet et al., 2013). Additionally, A_{Shock} did not differ from B_{Money}, and A_{Money} did not differ from B_{Shock}, p's = .70 and .80, respectively; but A_{Shock} was lower than C_{Money}, $F(1,22) = 5.64$, $p < .03$, whereas A_{Money} was higher than C_{Shock}, $F(1,22) = 7.84$, $p < .01$.

Our data demonstrate that relational responding can modulate and reverse evaluative ratings. It was shown that engaging participants in instructed arbitrary size judgments (bigger, smaller) between different CSs, and subsequently instructing that these relations map on to different intensities of imaginary electric shock (US-) or amounts of imaginary money (US+) lead to (1) subsequent liking ratings of the CSs that reflected these relational differences and (2) a reversal effect such that the CS paired with the smallest US- was rated more positively than the CS paired with the smallest US+.

As we have suggested previously (Molet et al., 2013), the reversal effect in evaluative ratings may be interpreted as a scaling effect (Frederick & Mochon, 2012) in which a shift occurs in the use of the valence scale itself rather than through any explicit, controlled evaluation of the CS. That is, more positive ratings of CSs paired with the smallest US- than CSs paired with smallest US+ may have occurred because participants based their evaluations of the CS under question by comparing it with related CSs of the same type. The merits of this interpretation, however, must await further empirical scrutiny before a role for arbitrary relational responding or other, contextual influences can be ruled out. Experiment 2 was conducted to further investigate the role of relational responding in generating altered or transformed evaluative ratings of arbitrary cues. Specifically, we sought to examine evaluative learning effects produced by CSs that participated in de novo arbitrary relations of comparison (more/less), and by adapting the procedures of Experiment 1 for use in a within-subjects design in which all participants consider both positive and negative dimensions of the CSs.

Experiment 2

The findings of Experiment 1 show for the first time that evaluative ratings of hypothetical money and shock outcomes may be altered in accordance with arbitrary relational responding. Arbitrary relations of bigger than and smaller than were established via instructions which stated, for instance, “B is bigger than A” and “C is bigger than B”, placing the CSs into the correct order of boxes and receiving corrective feedback. In this way, colour-coded boxes were treated as if they were bigger or smaller than each other despite being identical in size.

According to RFT, relations such as bigger than and smaller than are examples of comparative relations, which are first learned with non-arbitrary stimuli that differ along a specified physical dimension, such as size, but which may then be applied to any arbitrary stimuli, given appropriate contextual cues (Dymond & Barnes, 1995; Munnelly, Dymond & Hinton, 2010; Reilly, Whelan, & Barnes-Holmes, 2005; Whelan, Barnes-Holmes, & Dymond, 2006). Reilly et al. (2005) investigated effects of differing relational training histories on response latencies to a 5-series chain of more than and less than relations. First, non-arbitrary relational training and testing was undertaken to establish two contextual cues as signals for more than and less than, respectively. Participants were trained to select one of two comparisons of a greater quantity in the presence of the more-than contextual cue, and to select one of two comparisons of a lesser quantity in the presence of the less-than contextual cue, respectively, before being tested with novel stimuli. Next, participants were exposed to arbitrary relational training, which involved presentations of the contextual cues with physically dissimilar, arbitrary stimuli (A-B-C-D-E). One group was trained with all less than relations (i.e., A<B, B<C, C<D, D<E) whereby correct selections were predicted by the less than contextual cue. During testing, participants were presented with novel combinations of the stimuli and both contextual cues, in the absence of feedback. For instance, *mutual entailment* was tested with presentations of B>A, C>B, D>C and E>D. *Combinatorial entailment* involving one, two or three mediating steps was tested with presentations of A<C, B<D, C<E, C>A, D>B and E>C (one-step), A<D, B<E, D>A and E>B (two-step), and A<E and E>A (three-step). Reilly et al. (2005) found that response latencies decreased linearly across one-, two- and three-step trials.

In Experiment 2, we sought to replicate and extend the effects shown in Experiment 1 by employing training and testing procedures from the RFT literature (e.g., Munnelly et al., 2010) to create comparative relational networks that do not confer valence independently; that is, it is necessary to establish a psychological meaning or function for one member of the relation, such as imaginary shock or money outcomes, and to examine subsequent spreading of this effect to other, indirectly related stimuli. Thus, it was predicted that choices of money or shock outcomes would be altered in line with the derived relational network of combined more than and less than relations. That is, after training A<B<C<D<E and instructing participants that C was paired with either money or shock, we expected choices of each member of the relational network would be altered in accordance with the derived relational network E>D>C>B>A, with E chosen more often than A in the presence of money, and the opposite trend in the presence of shock. Furthermore, we expected that choices would be modulated (i.e., increase or decrease) when participants were asked which outcome they *most* or *least* wished to receive, with E chosen more often than A in the presence of money and *most* and shock and *least* combinations, and the opposite trend in the presence of shock and *most* and money and *least*. We also predicted that E would be evaluated more positively than A in the context of money, and A would be evaluated more positively than E in the context of shock, with valence ratings conforming to a linear trend across the members of the derived relational network.

Method

Participants

Twenty-five participants (3 men), aged between 18 and 24 years old (M_{age} = 20.70, *SD* = 2.74) were recruited from Swansea University in return for partial course credit. Based on the aforementioned power analysis (Hofmann et al., 2010), twelve participants were required. However, because the effect size of the manipulations used in Experiment 2 is as yet unknown, we assumed that a sample size twice that employed in Experiment 1, in a within subjects-design, would be capable of detecting the predicted effects.

Apparatus and stimuli

Two arbitrary images were employed as the contextual cues for MORE-THAN and LESS-THAN, respectively[1]. Twenty-eight stimulus sets consisting of images of varying quantities of objects were used during non-arbitrary relational training and testing. For the arbitrary relational training and testing phases, five abstract Kanji images were used as stimuli and predicted to form a 5-member linear relational network (A-B-C-D-E; see Figure 2). In the evaluative testing phase, ratings were again provided using the SAM.

Insert Figure 2 About Here

Procedure

Sessions were approximately 45 minutes duration. All participants received less than non-arbitrary and arbitrary relational training and testing followed by evaluative learning and testing. The relational training and testing sequence was based on Munnelly, Freegard and Dymond (2013): *Phase 1: Non-arbitrary Relational Training and Testing; Phase 2: Constructed Response Non-arbitrary Relational Training and Testing; Phase 3: Arbitrary Relational Training; Phase 4: Arbitrary Relational Test 1; Phase 5: Arbitrary Relational Test 2*. Next, participants were exposed to *Phase 6: Evaluative learning and testing*.

During Phases 1-5, a blank yellow square appeared first in the upper left-hand side of the screen. During Phase 1, the contextual cue (i.e., the image designated to represent LESS-THAN or MORE-THAN) appeared in the upper centre of the screen, and a blank yellow square was presented following a 1 s delay in the upper right-hand side of the screen. Next, two comparison stimuli appeared simultaneously in the lower third of the screen (left/right positioning was counterbalanced). To make a response, participants were instructed to “drag” one of the two comparison stimuli and “drop” it in the upper-right blank yellow square. Once selected, two

[1] In line with convention (e.g., Dymond & Whelan, 2010), we refer to the actual images employed as contextual cues in capitals (i.e., MORE-THAN, LESS-THAN) and to emphasize that real words were not presented as cues.

confirmatory response buttons appeared at the bottom of the screen labelled “Finish Trial” and “Start Again”, respectively. Pressing the “Start Again” button cancelled the selection and resulted in all stimuli returning to their positions before the selection was made. Pressing the “Finish Trial” button was followed by feedback. When a participant made a correct response, feedback consisted of the sample, contextual cue, the comparison stimulus the participant had selected on the previous trial, and the word “Correct!” accompanied by brief audible beep. Following an incorrect selection, feedback consisted of the sample, contextual cue, the comparison stimulus selected, and the word “Wrong”. During all testing trials, no feedback was presented. The inter-trial interval (ITI) was 1 s.

The presentation of stimuli differed during Phases 2-5. That is, participants were presented with a blank yellow square, followed by a contextual cue, and another blank yellow square in the upper portion of the screen. Similar to Phase 1, two comparison stimuli were again presented on the lower portion of the screen but the sample stimulus in the upper left-hand side of the screen was now replaced with a blank yellow square. During these phases, participants were required to “construct” their responses, from left-to-right in the upper portion of the computer screen. Participants were instructed to place one of the comparison stimuli in the upper-left blank yellow square, and the other comparison in the upper-right blank yellow square. Again, all training trials were followed by feedback, whereas feedback was omitted during all test phases.

A task “feedback thermometer” was displayed in the centre, right-hand side of the screen during all training and testing phases (Fienup, Covey & Critchfield, 2010). During training, the thermometer displayed the criterion needed to complete training (e.g., “You need this many correct to move on: 10”), the current number of correct responses (e.g., 6 out of 10), and was incremented following every correct response. During testing, the thermometer displayed the total number of trials in the particular test phase and the current trial number, and the latter was incremented following every response.

Phase 1: Non-arbitrary Relational Training and Testing. The purpose of this phase was to establish the images designated MORE-THAN and LESS-THAN as contextual cues for more than and less than relational responding by reinforcing selections of comparison stimuli of varying quantities in the presence of each respective cue. For example, on a given trial, participants were presented with a sample (e.g., two balls), a contextual cue (e.g., more than), and a blank yellow square in the upper portion of the screen. Two comparison stimuli (e.g., one and four balls) were also presented on the lower portion of the screen. In this instance, placing the comparison stimulus containing one ball in the blank yellow square counted as a correct response. On the other hand, if two balls were again presented as the sample, alongside the contextual cue for less than, and one and four balls as comparison stimuli, placing the comparison stimulus containing four balls in the blank yellow square was reinforced. All training trials were followed by feedback and by the ITI. Four stimulus sets were employed and mastery criterion was 10 consecutive correct responses. Once met, participants proceeded immediately to the non-arbitrary relational test.

The non-arbitrary relational test was similar to training except that four novel stimulus sets were presented and all feedback was omitted. Participants were presented with a total of eight test trials and were required to respond correctly across all trials in order to progress. If this criterion was not met, they were re-exposed to non-arbitrary relational training involving the same four stimulus sets, which was again followed by the non-arbitrary relational test.

Phase 2: Constructed Response Non-arbitrary Relational Training and Testing. The purpose of this phase was to train and test participants to “construct” the relation between two comparison stimuli, in the presence of a particular contextual cue (e.g., the arbitrary images designated MORE-THAN and LESS-THAN). On each trial, participants were presented with a blank yellow square, a contextual cue, and another blank yellow square in the upper portion of the screen and two comparison stimuli in the lower portion. For example, they might have been presented with the MORE-THAN cue, and pictures of four and two bicycles, respectively, as the comparisons. A correct response in that case would have involved “dragging” and “dropping” the four bicycles to the upper-left blank yellow square and the two bicycles to the upper-right blank yellow square, in that sequence. On the other hand, if the LESS-THAN cue was presented with the same comparisons, then placing the two bicycles in the upper-left square, and the four bicycles in the upper-right square was correct. Feedback was presented following all training trials. Four stimulus sets were presented during training, and mastery criterion was set at 10 consecutive correct responses. If criterion was met, participants were immediately exposed to the non-arbitrary relational test phase. If they failed to meet criterion within 240 training trials, they were then exposed to a second non-arbitrary relational training phase, with four novel stimulus sets.

The constructed response non-arbitrary relational test was similar to training except that four novel stimulus sets were employed and feedback was omitted. Participants were exposed to eight test trials, and were required to respond correctly across all test trials to progress to the next phase of the experiment. If criterion was not met, participants were re-exposed to non-arbitrary relational training with the same four stimulus sets, which was again followed by the non-arbitrary relational test phase, as necessary.

Phase 3: Constructed Response Arbitrary Relational Training. Similar to Phase 2, participants were presented with a blank yellow square, a contextual cue, and another blank yellow square in the upper portion of the screen. Again, two comparison stimuli were presented simultaneously below. However, during this phase, the comparison stimuli consisted of arbitrary images, which are labelled for purposes of clarity, A, B, C, D, and E (Figure 2). Participants were presented with training trials in a linear order, A<B, B<C, C<D and D<E, in the presence of the LESS-THAN contextual cue (see Figure 2). The four training pairs were presented for a total of three times each, resulting in a block of 12 training trials. Mastery criterion for the arbitrary relational training phase was set at 12 out of 12 correct responses (i.e., 100% accuracy) on any given block. Training blocks were repeated until criterion was met.

Phase 4: Constructed Response Arbitrary Relational Test 1. Here, participants were exposed to an arbitrary relational test phase that probed for the properties of mutual entailment alongside maintenance of the baseline arbitrary training relations. All feedback was omitted and participants were presented with eight test trials each presented four times for a total of thirty-two test trials (Figure 2). The mutual entailment test trials consisted of B>A, C>B, D>C and E>D. Mastery criterion for this phase was set at a minimum mean of 12 out of 16 (i.e., 75% accuracy) correct responses on the baseline relations. For the mutually entailed relations, participants were required to make 3 out of 4 correct responses (i.e., 75% accuracy) on each individual mutually entailed test trial. If participants were successful in meeting criterion for both baseline and mutually entailed relations, they progressed to a second arbitrary relational test phase. If they failed to reach this mastery criterion, they were re-exposed to the experimental task from the very beginning for a maximum of three further exposures.

Phase 5: Constructed Response Arbitrary Relational Test 2. Participants were presented with probes for one- and two-node combinatorially entailed relations, as well as the four baseline relations. Each test trial was presented four times, in a quasi-random order, which resulted in a total of 56 test trials (see Figure 2). Participants were again required to make a minimum of 12 out of 16 correct responses on the baseline relations and all were presented with the same one- and two-node combinatorially entailed relations. Participants had to make a minimum of 3 out of 4 correct responses on each individual one- and two-node test trial in order to progress to Phase 6. If this criterion was not met, they were re-exposed to the entire task from Phase 1, for a maximum of three further exposures.

Phase 6: Evaluative Learning and Testing. On every trial, participants were instructed to "Imagine that [stimulus C] was followed by shock" or to "Imagine that [stimulus C] was followed by £100". The instruction appeared in the centre of the screen and the arbitrary image corresponding to stimulus C was shown with either an image of a lightning bolt to depict shock or an image of stacked £20 GBP banknotes to depict money, respectively (see Figure 3). Immediately below were shown a pair of stimuli from the arbitrary relational phases (i.e., AB, BC, CD, DE, AC, BD, CE, AD, BE, and AE). Stimulus pairs were presented in random order and shown on the left and right of the screen spaced approximately 10 cm apart. Participants answered the following two successive questions, which were presented immediately above each stimulus pair: "which would you most like to receive?" and "which would you least like to receive?" by clicking on one of the two stimuli. Participants were then instructed to give their "immediate emotional reaction" to each of the successive cues from the pair shown earlier in the trial by using the SAM valence scale (Figure 3).

Insert Figure 3 About Here

A total of eighty evaluative learning and testing trials were presented; forty involving imagined shock outcomes and forty involving imagined money outcomes. Trial order was quasi-randomized with the only constraint that no more than two consecutive trials of the same outcome could be presented.

Results & Discussion

Three participants (P12, P13 and P14) withdrew during the relational training and testing phases, leaving a final n = 22 in Experiment 2. Table 1 shows the number of trials to criterion and the number of correct responses in the non-arbitrary and arbitrary training and testing phases in Experiment 2. All but five of the twenty-two participants (P14, P16, P17, P18 and P25) passed Phase 1 on the first exposure, all passed Phase 2 in one exposure and all needed no more than two exposures to the arbitrary relational tests in Phase 4 and 5. These data are in line with previous research (Munnelly et al., 2013).

Insert Table 1 and Figure 4 About Here

Participants' evaluative choices were consistent with the predicted arbitrary relational network of more than and less than relations (i.e., E>D>C>B>A). Figure 4 shows the mean choices of each stimulus when asked to imagine each was associated with a hypothetical US outcome they most (Figure 4A, 4B) or least (Figure 4C, 4D) wished to receive. Choices of E were consistently made when money was the hypothetical US and participants were asked what they would most like to receive and when shock was the hypothetical US and asked what they would least like to receive (Figure 4A, 4D). The opposite pattern was observed, and A chosen consistently more often, when shock was the hypothetical US and cue participants were asked what they would most like to receive and when money was the hypothetical US and asked what they would least like to receive (Figure 4B, 4C).

A repeated measures ANOVA with Greenhouse Geisser correction indicated that choices in response to the question, "what would you most like to receive?" when money was the hypothetical outcome (Figure 4A), significantly differed across the five stimuli from the relational network, $F(1.094, 22.98) = 8.912$, $p < .05$, $\eta p^2 = .298$.

Choices in response to the question, "what would you most like to receive?" when shock was the hypothetical outcome (Figure 4B), differed statistically significantly across the five stimuli from the relational network, $F(1.10, 23.14) = 7.070$, $p < .05$, $\eta p^2 = .252$.

Choices in response to the question, “what would you least like to receive?” when money was the hypothetical outcome (Figure 4C), differed statistically significantly across the five stimuli from the relational network, $F(1.105, 23.21) = 6.981$, $p < .05$, $\eta p^2 = .249$.

Finally, choices in response to the question, “what would you least like to receive?” when shock was the hypothetical outcome (Figure 4D), differed statistically significantly across the five stimuli from the relational network, $F(1.09, 22.89) = 7.184$, $p < .05$, $\eta p^2 = .255$.

As Figure 4 illustrates, a gradient of choices was observed across the five arbitrary stimuli from the relational network, which was in line with the predicted more than and less than relations (E>D>C>B>A). This gradient of responding was modulated by the hypothetical US assumed to be present (money or shock) and by the questions, “what would you most/least like to receive?” during the evaluating testing trials. Polynomial trend analysis was conducted to determine the linear terms used to describe the shape of the obtained gradients in responding. Trend analyses revealed a significant linear trend in choices of the different members of the relational network across all US outcomes and most/least question combinations: money/most: $F(1, 21) = 9.282$, $p = .006$, $\eta p^2 = .307$ (Figure 4A); shock/most: $F(1, 21) = 7.408$, $p = .013$, $\eta p^2 = .261$ (Figure 3B); money/least: $F(1, 21) = 7.257$, $p = .0014$, $\eta p^2 = .257$ (Figure 3C); and shock/least: $F(1, 21) = 7.418$, $p = .013$, $\eta p^2 = .261$ (Figure 3D). This confirms that E was chosen more often and in a linear trend when the evaluative question included the money/most and shock/least combinations, and least often and in a linear trend when the evaluative question included the money/least and shock/most combinations.

As Figure 5 shows, higher valence ratings were made of each stimulus from the relational network in the assumed presence of money and shock, and all ratings were ranked in accordance with trained and tested relations. That is, stimulus A tended to be rated lowest overall, and stimulus E highest, when the money outcome was imagined, while this pattern was reversed in the imagined presence of the shock outcome. A 5 (Stimulus: A, B, C, D, E) x 2 (US valence: Money and Shock) ANOVA with repeated measures on both factors performed on the SAM valence ratings revealed a main effect of US valence, $F(1, 21) = 35.167$, $p < .001$, $\eta^2_p = .63$, but indicated no main effect of stimulus, $F(4, 84) = 1.22$, $p = .31$. Of main interest, the stimulus x US valence interaction was significant, $F(4, 84) = 7.85$, p < .001, $\eta^2_p = .27$.

Insert Figure 5 About Here

Overall, the findings of Experiment 2 show that participants' choices of hypothetical outcomes involving shock and money USs were transformed in accordance with a relational network of derived less than and more than relations, and further modulated by the questions, "what would you most/least like to receive?" into linear trends (Figure 4). Valence ratings made for each stimulus from the relational network in the hypothetical presence of each outcome also conformed to a linear trend in accordance with the trained and tested relations (Figure 5).

General Discussion

The present findings add to research supporting the role of relational processes in evaluative learning (Gast & De Houwer, 2012; Hughes et al.,, 2016; Molet et al., 2013; Zanon et al., 2012, 2014). More specifically, we showed that arbitrary relational properties, which were manipulated through relational information presented (Experiment 1) or contextually trained (Experiment 2) involving more than and less than relations between the CSs, critically determine subsequent evaluations of those CSs. Indeed, we found that relational effects reversed evaluative learning effects (Experiment 1) as CSs were evaluated more positively after being related via instructions to hypothetical electric shocks, rather than money of relatively weaker intensity. However, we found no evidence for this reversal effect in Experiment 2 when a within-subjects design and procedures from RFT were used. It is possible therefore that a scaling account

(Frederick & Mochon, 2012) may better fit the data from Experiment 1, where a between subjects design was employed, than the within-subjects design in Experiment 2 where participants experienced both aversive and appetitive hypothetical outcomes.

A classic associative perspective on evaluative learning holds that CS evaluations reflect mere affect or response transfer from the US to the CS (Hofmann et al., 2010). For instance, the affect misattribution model (Jones, Olson, & Fazio, 2010) proposes that evaluative learning results from the implicit misattribution of affective responses generated by a US to its associated CS. According to associative accounts (e.g., Lagnado et al., 2007), associations are explanatory mechanisms used to explain the effects of stimulus pairings. Unlike propositions, associations are neither valid nor invalid because they contain no relational information about CSs or the relationship between CSs and the US. This was the case in the present experiments where the CSs and US were never explicitly paired or associated (except through relational instructions and relational training). Modifications of existing associative based models to accommodate a role for relational information over and above that for CS-US pairings is possible (e.g., Melchers, Lachnit & Shanks, 2004), but several authors (e.g., Zanon et al., 2014) have highlighted that post hoc revisions of these models ultimately require knowledge of how the stimuli are related and whether or not the relation holds (i.e., if it is true). Doing so then makes associative accounts indistinguishable from propositional accounts (De Houwer, 2009).

The present findings share some overlap with propositional accounts of evaluative learning (Mitchell et al., 2009; Zanon et al., 2012, 2014), which stress the role of declarative (relational) knowledge about the CS-US relationship and conscious inferential processes. For instance, Fiedler and Unkelbach (2011) showed that participants formed different evaluations of CSs depending on whether the CSs were said to entertain a positive (i.e., friend) or negative (i.e., enemy) relation to the USs (see also, Kattner, Ellermeier, and Tavakoli, 2012). Recently, considerable theoretical debate has taken place about building bridges between cognitive based accounts of human learning phenomena such as evaluative learning and functional based approaches like RFT (De Houwer, 2009, 2011; De Houwer, Gawronski, & Barnes-Holmes, 2013; Hughes et al., 2016; Proctor & Urcuioli, 2015; Stewart, 2016). The present findings contribute to these efforts by showing that relational information in the form of instructions about bigger than relations between CSs (Experiment 1) or contextually controlled arbitrarily applicable comparative relations of more than and less than (Experiment 2) are capable of modulating evaluative learning as measured by choices of hypothetical shock or money USs.

More broadly, our findings indicate that closer connections between RFT and propositional accounts may benefit both fields of research (De Houwer, 2011; Stewart, 2016). Regarding evaluative learning, we found that RFT leads to novel predictions about how CS-US relations may shape CS evaluations and how such evaluations may be modulated as a function of the contextually controlled arbitrarily applicable relations established among CSs during training and testing. Specifically, selections of individual members of the relational network A<B<C<D<E presented as hypothetical shock or money USs during evaluative learning testing were transformed in accordance with arbitrary comparative relations of more than and less than and modulated by the presence of the ‘most’ or ‘least’ relational information cues. Participants’ relational evaluations or evaluative choices conformed to the gradient A<E or E>A, depending on whether the outcome was most or least desired, and the resulting evaluative learning effects resembled a gradient of responding ranging for most to least preferred (Figure 4).

To our knowledge, this is the first study to synthesize procedures and concepts from RFT research on arbitrary comparative relations with an evaluative learning task design. As such, our procedures may also contribute to propositional accounts of evaluative learning in the following ways. First, as outlined in the Introduction, propositions refer to arrangements of stimuli that are either valid or invalid and specify how the stimuli are related or unrelated. Here, the non-arbitrary and arbitrary relational training and testing phases resulted in the unambiguous specification or derivation of more than and less than relations among members of the relational network which formed the relational basis along which hypothetical choices were evaluated and framed. In this way, our findings provide a directly traceable experimental history with which stimulus propositions are formed which then resulted in clear statements about how the stimuli are related. Second, our findings show that providing additional relational information in the form of questions asking participants which outcome they most or least wanted to receive modified the manner by which CSs were related and controlled the resulting effects accordingly. This highlights how relational evaluations may be impacted by propositional-based relational information about CSs since participants presumably believed such propositions corresponded to how the experimental task was arranged (Zanon et al., 2014). Third, the current RFT based procedures offer considerable flexibility in both the range and type of arbitrary stimulus relations that might be employed to investigate evaluative learning. For instance, in Experiment 2, participants were trained exclusively in all less than arbitrary relations but other training designs such as all more than or a combination of less than and more than relations are possible and may yield different outcomes on tests of evaluative learning (Munnelly et al., 2010). Also, the current five-term relational network may be extended to seven-terms (Whelan et al., 2006) and thus increase the number of novel predicted evaluative learning outcomes that might emerge at test. Further research on these alternative designs is warranted. Finally, we used comparative relations (using the dimension of size and quantity, etc.), but RFT emphasizes other families of relations, such as coordination and opposition, distinction, and hierarchy among others (Dymond & Roche, 2013). To our knowledge, these other types of stimulus relations have not yet been applied to evaluative learning but certainly warrant further empirical attention.

Although preliminary, the present study has several potential limitations. It is possible that, across both experiments, our evaluative learning testing phases were susceptible to demand characteristics. In the absence of any cover story or other such deception, this may have lead to our participants becoming aware of the hypotheses and making their ratings and selections accordingly. The absence of implicit measures before and after the evaluative learning and testing phase may have made our procedures susceptible to demand effects. It is possible therefore that greater sensitivity may be obtained by administering an implicit test of evaluative learning in a pre-test/post-test design. Such a design would be capable of unambiguously detecting the effects of arbitrarily applicable relational responding (Hughes et al., 2011), as well as mitigating any potential demand effects. Future research should address these issues and extend the present findings by testing for the effects of a reversal in the arbitrary relational network on implicit and explicit evaluations (Molet et al., 2013; Reilly et al., 2005).

In conclusion, the present preliminary findings highlight a role for arbitrarily applicable relations of more than and less than in evaluative learning, extend existing analyses of the impact of relational information, and outline important issues that warrant further empirical attention.

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Figure Captions

Figure 1. Design and results from Experiment 1. The upper panels show the design of evaluative learning and testing tasks. The conditioned stimuli (CSs) were constant in size but differed in colour (A, B, C) and participants were informed that “B is bigger than A” and “C is bigger than B”. Half of the participants were trained to associate CSs with imaginary Money (Group Money) and the remaining participants were trained to associate CSs with imaginary Shock (Group Shock). The lower panel shows the evaluative ratings given to A, B and C by participants in each group. Error bars represent standard error of the mean.

Figure 2. Stimuli and trial types used in Experiment 2. (A) Kanji images employed during arbitrary relational training and testing in Experiment 2. The images are labelled A, B, C, D, and E (participants were never exposed to these labels). (B) Relations trained during arbitrary relational testing (A<B, B<C, C<D and D<E); Mutually entailed relations tested during arbitrary relational testing (B>A, C>B, D>C, and E>D); Combinatorially entailed 1-node (A<C, B<D, C<E< D>B and E>C) and 2-node (A<D, B<E and D>A) relations tested during arbitrary relational testing. The inequality symbols, < (less than) and > (more than), denotes the contextual cue presented and indicates which comparison should be selected over the other, with the reinforced comparison shown on the left and the unreinforced comparison on the right. It is important to note that the actual contextual cues used consisted of abstract visual images and not the inequality symbols described here, which are used for the purposes of clarity.

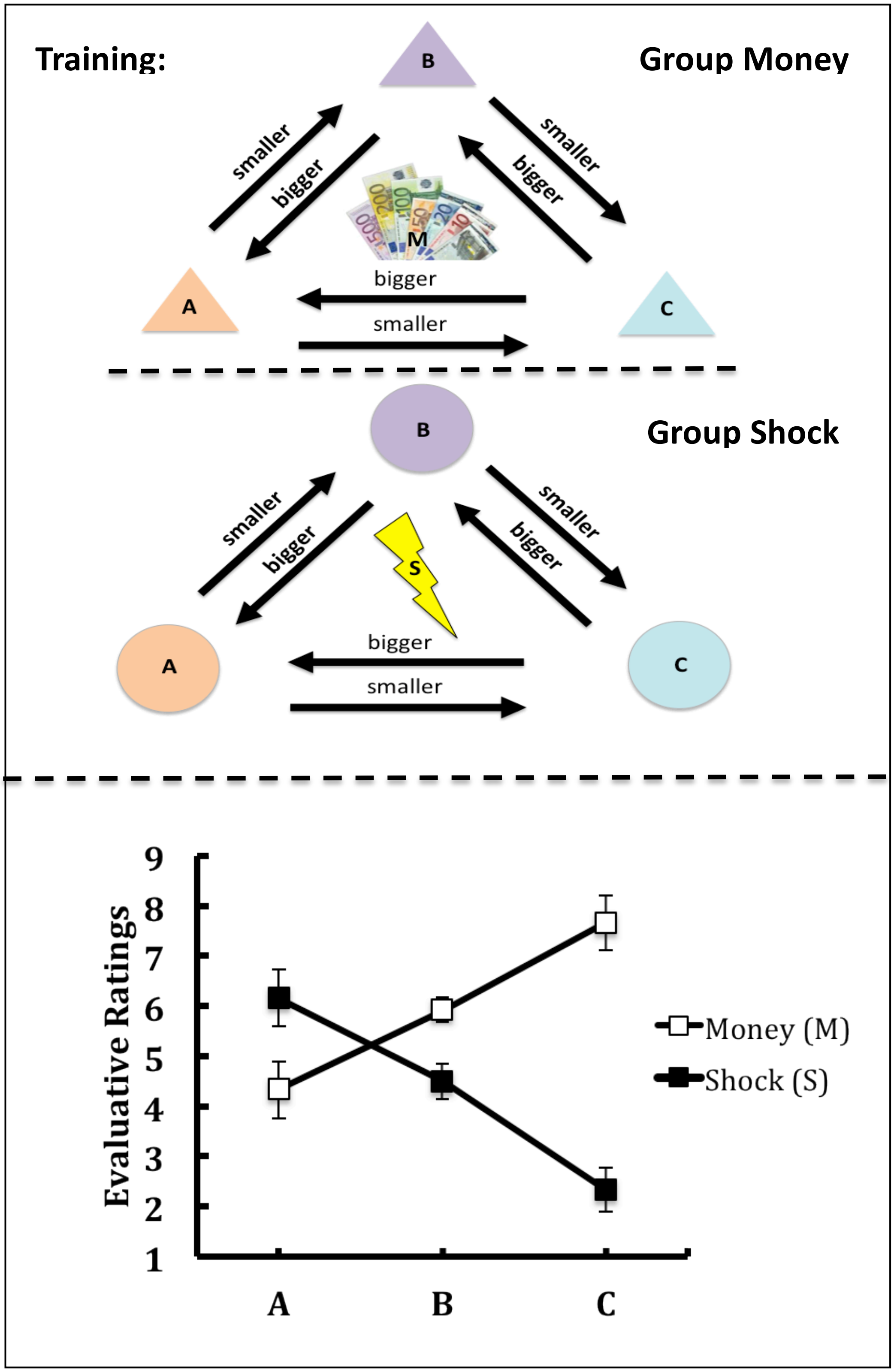
Figure 3. Evaluative learning and testing trial layouts in Experiment 2. (A) Participants were instructed to imagine that stimulus C was followed by a shock, and were then presented with two stimuli from the relational network and asked to select which one they would most like to receive (left panel) or least like to receive (right panel). (B) Participants gave their emotional reaction to each of the stimuli by clicking on the SAM. (C) Participants were instructed to imagine that stimulus C was followed with £100, and were then presented with two stimuli from the relational network and asked to select which one they would most like to receive (left panel) or least like to receive (right panel). (D) Participants gave their emotional reaction to each of the stimuli by clicking on the SAM. The arrow indicates the sequence in which the tasks were presented.

Figure 4. Mean choices of each member of the relational network (A to E) given money and shock USs and evaluations of least and most likely, respectively, from Experiment 2. (A) Mean choices participants would most like to receive given the money US. (B) Mean choices participants would most like to receive given the shock US. (C) Mean choices participants would least like to receive given the money US. (D) Mean choices participants would least like to receive given the shock US. Error bars represent standard error of the mean.

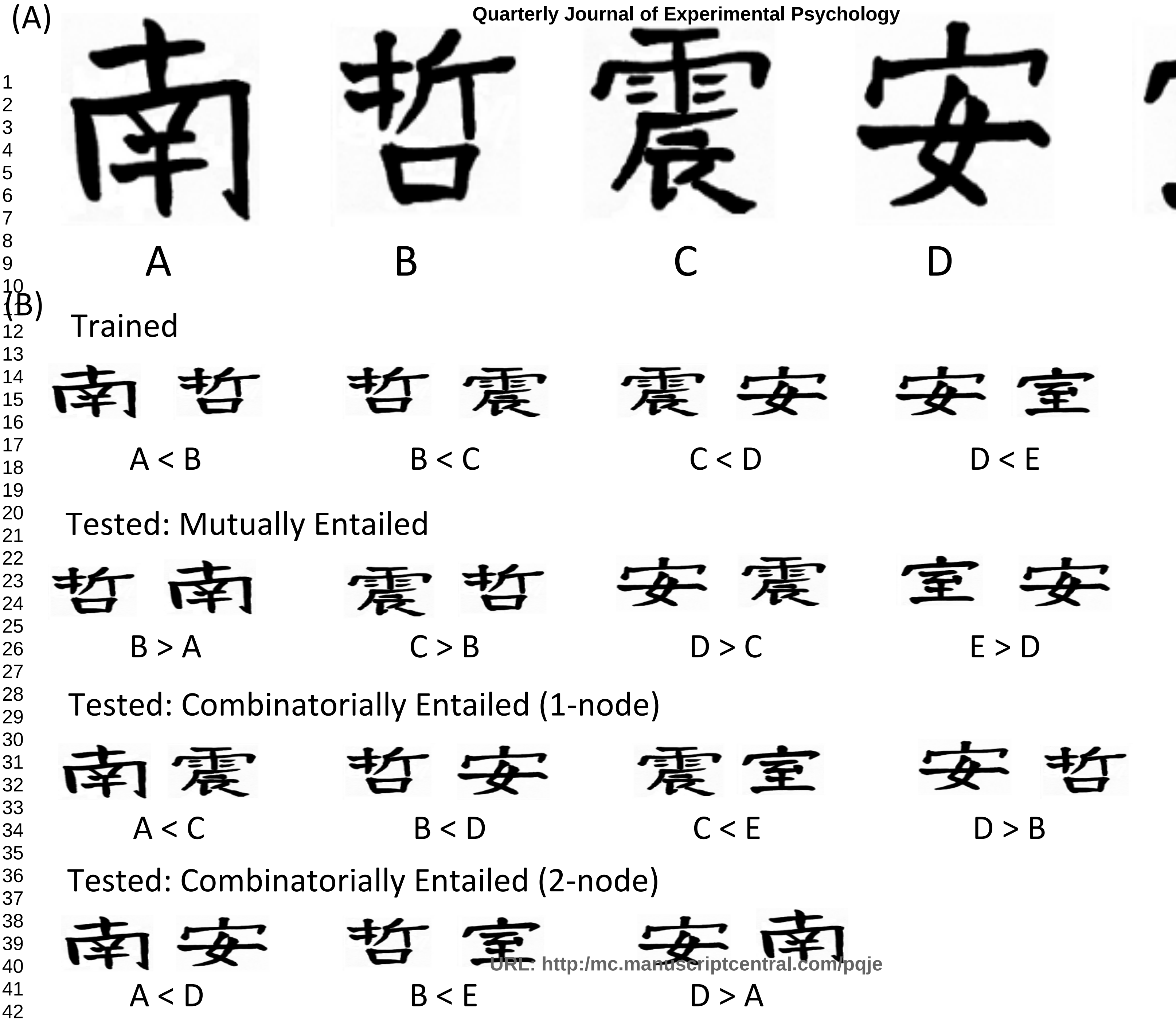
Figure 5. Mean valence ratings for each member of the relational network (stimulus A to E) given shock and money USs, respectively, from Experiment 2. Error bars represent standard error of the mean.

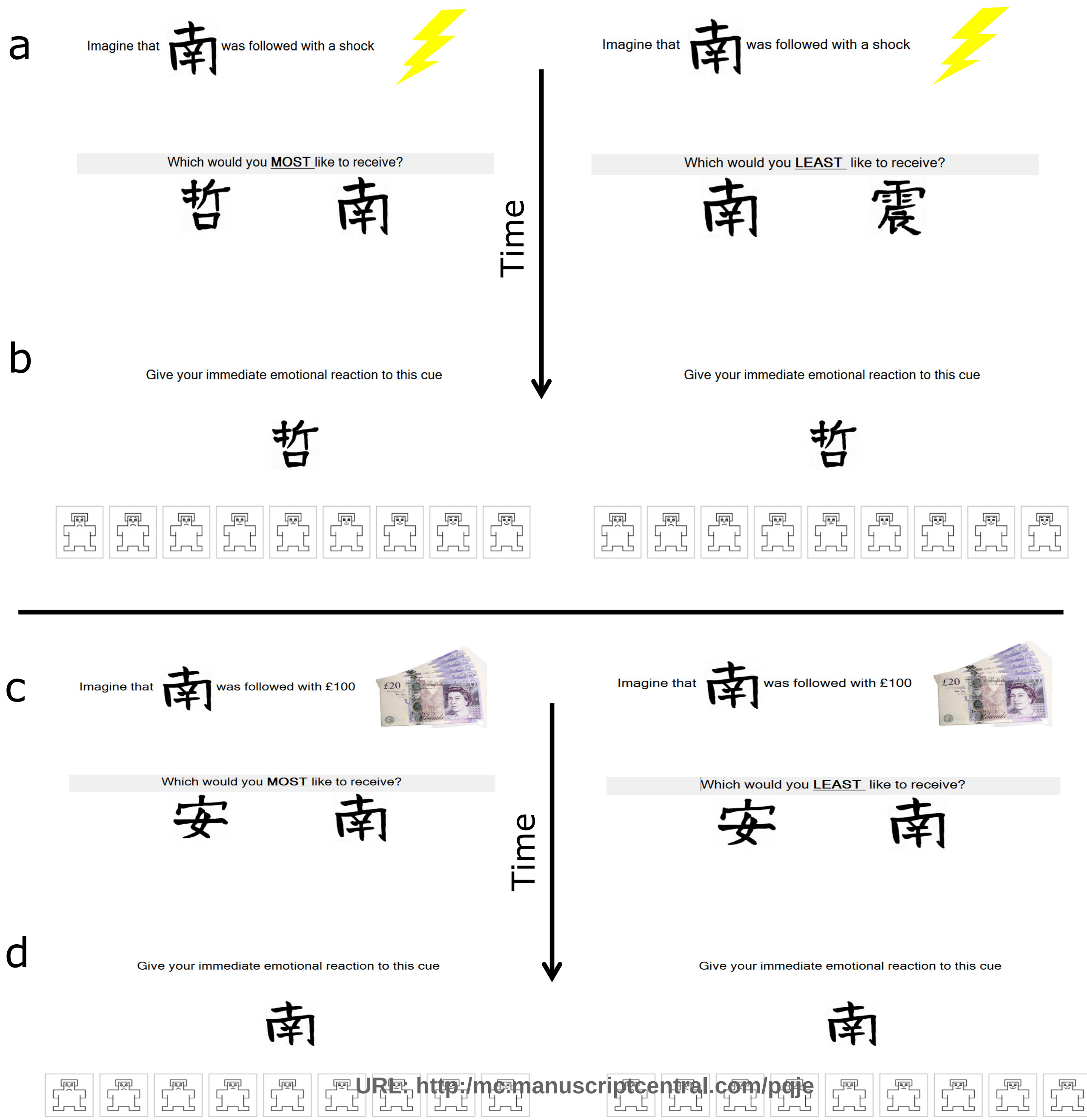
Table 1. Trials to criterion during nonarbitrary and arbitrary training and testing phases in Experiment 2. CR = Constructed-response; Baseline = unreinforced directly trained relations; ME = Mutually Entailed relations; CE1 and CE2 = one- and two-node combinatorially entailed relations. Data are shown for the number of correct responses on baseline and mutually entailed relations during Test 1 and on baseline and one- and two-node relations during Test 2. Subsequent training and testing exposures are given on separate lines. * = participant withdrew.

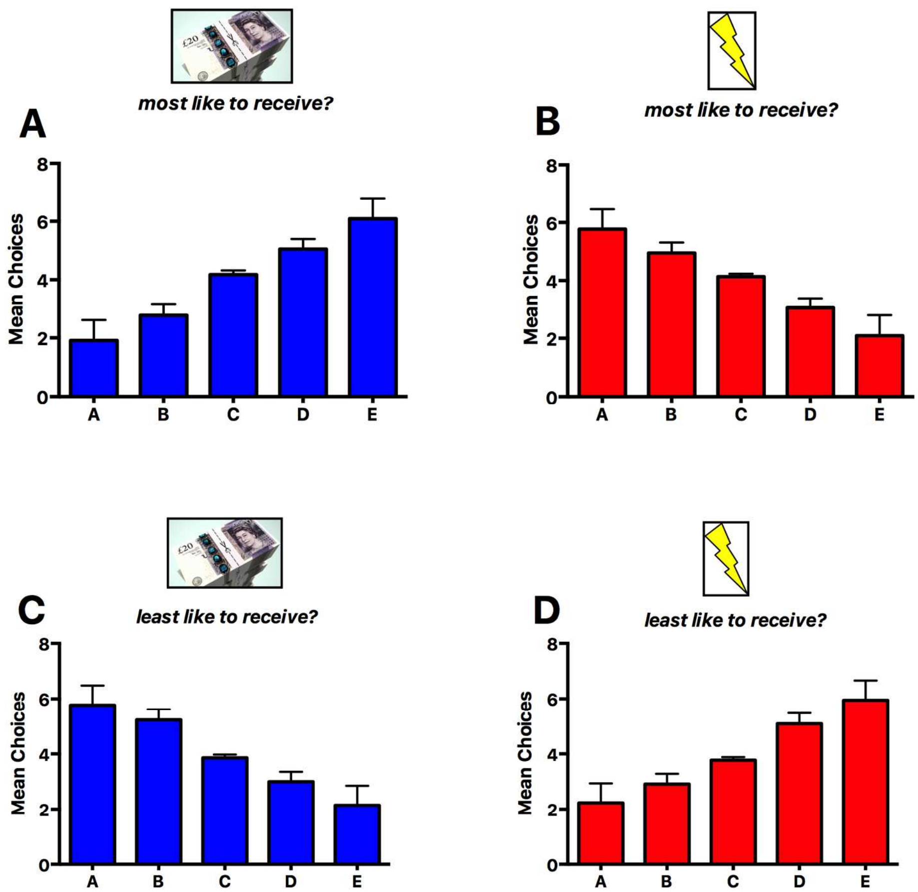
P	Phase 1: Nonarbitrary Train (& Test)	Phase 2: CR Nonarbitrary Train (& Test)	Phase 3: CR Arbitrary Relational Train	Phase 4: CR Arbitrary Relational Test 1		Phase 5: CR Arbitrary Relational Test 2		
				Baseline	ME	Baseline	CE1	CE2
1	12 (8)	10 (8)	48	16	15	16	23	16
2	13 (8)	10 (8)	48	12	14			
		10 (8)	24	16	16	16	23	15
3	12 (8)	10 (8)	84	14	16	16	22	16
	11 (8)	10 (8)	12	16	16	16	24	16
4	12 (8)	10 (8)	36	15	16			
	11 (8)	10 (8)	48	18	13	13	22	16
5	29 (8)	10 (8)	24	16	16	16	24	16
6	10 (8)	10 (8)	25	16	16	16	23	16
7	10 (8)	10 (8)	24	14	0			
	13 (8)	10 (8)	12	16	16	16	24	16
8	30 (8)	10 (8)	24	16	16	16	24	16
9	10 (8)	10 (8)	36	16	16	16	24	16
10	12 (8)	10 (8)	60	16	16	16	24	16
11	10 (8)	10 (8)	24	16	16	16	24	16
12*	11 (8)	10 (8)	48	16	16	16	18	10
	10 (8)	10 (8)	48	16	16	16	9	7
13*	13 (8)	10 (8)	48	16	16	15	16	0
14*	20 (7), 20 (4)	10 (8)	84	15	16	15	10	15
	31 (8)							
15	15 (8)	10 (8)	36	15	16	15	23	16
16	18 (7), 10 (8)	10 (8)	24	15	16	16	20	15
	31 (8)	10 (8)	12	15	16	15	23	16
17	10 (7), 10 (8)	10 (8)	24	16	16	16	24	16
18	13 (7), 17 (8)	14 (8)	12	14	16			
	10 (8)	10 (8)	12	16	16	16	23	16
19	13 (8)	10 (8)	24	16	16	16	24	16
20	26 (8)	17 (8)	36	16	16	15	16	16
	11 (8)	10 (8)	36	16	16	16	24	16
21	10 (8)	10 (8)	36	16	15	16	24	16
22	14 (8)	10 (8)	36	16	16	0	1	0
	10 (7), 16 (8)	10 (8)	24	16	16	16	24	16
23	19 (8)	10 (8)	60	16	16	14	11	9
	17 (8)	19 (8)	24	16	16	16	24	16
24	13 (8)	10 (8)	36	16	15	16	24	16
25	20 (2), 12 (8)	10 (8)	36	16	16	16	24	16



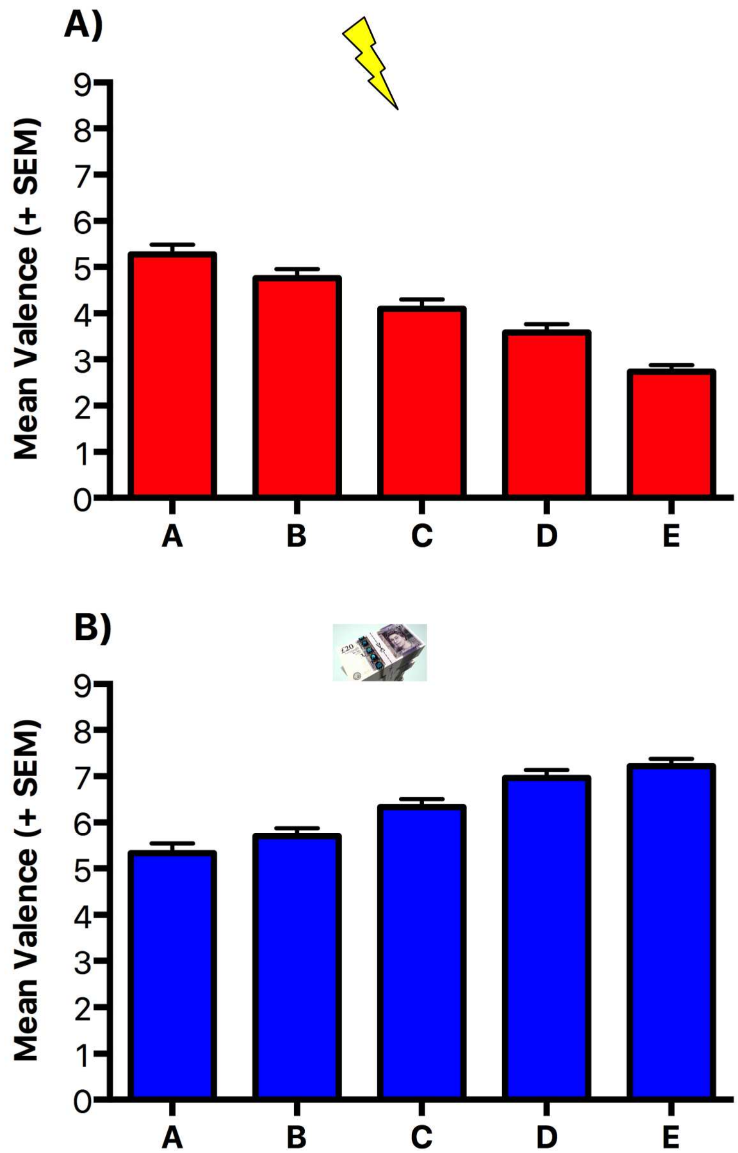
Training:
Group Money
B
smaller
bigger
M
A
C
bigger
smaller
Group Shock
B
smaller
bigger
S
A
C
bigger
smaller
Evaluative Ratings
9
8
7
6
5
4
3
2
1
A
B
C
Money (M)
Shock (S)


(A)
A
B
C
D
(B)
Trained
A < B
B < C
C < D
D < E
Tested: Mutually Entailed
B > A
C > B
D > C
E > D
Tested: Combinatorially Entailed (1-node)
A < C
B < D
C < E
D > B
Tested: Combinatorially Entailed (2-node)
A < D
B < E
D > A


a
Imagine that 南 was followed with a shock
Which would you MOST like to receive?
哲 南
Imagine that 南 was followed with a shock
Which would you LEAST like to receive?
南 震
Time
b
Give your immediate emotional reaction to this cue
哲
Give your immediate emotional reaction to this cue
哲
c
Imagine that 南 was followed with £100
Which would you MOST like to receive?
安 南
Imagine that 南 was followed with £100
Which would you LEAST like to receive?
安 南
Time
d
Give your immediate emotional reaction to this cue
南
Give your immediate emotional reaction to this cue
南



176x161mm (300 x 300 DPI)



165x224mm (300 x 300 DPI)