Derived Same and Opposite Relations Produce Association and Mediated Priming

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Abstract

The present study examined if derived relations under contextual control could produce association and mediated priming in lexical decision tasks. Participants' responses to nonarbitrary stimulus relations of Sameness and Opposition were brought under contextual control. Next, participants were exposed to arbitrary matching-to-sample training in the presence of these same contextual cues, using word-like nonwords as stimuli (the participants were told these were "foreign" words). Participants were then given a series of lexical decision tasks, which included the foreign words and previously unseen "nonsense" stimuli. The task was to decide whether both stimuli were foreign words. Response times to pairs of foreign words were reliably faster when both of the stimuli were related than when they were unrelated; that is, association and mediated priming effects for related stimuli were demonstrated.
Keywords: derived relations, contextual control, priming, response time (RT), association priming, mediated priming

Resumen

El presente estudio examinó si relaciones derivadas bajo control contextual podrían producir priming mediado y de asociación en tareas de decisión léxica. Las respuestas de los participantes a relaciones no arbitrarias de Igualdad y Oposición se pusieron bajo control contextual. Tras ello, los participantes fueron expuestos a un entrenamiento arbitrario en igualación a la muestra en presencia de dichas claves contextuales, utilizando como estímulos no-palabras similares a palabras reales (se les dijo que se trataba de palabras extranjeras). A continuación se les presentó una serie de tareas de decisión léxica en las que aparecían las "palabras extranjeras" y estímulos sin sentido novedosos (previamente no presentados). La tarea consistía en decidir si ambos estímulos eran palabras extranjeras. Los tiempos de reacción a los pares de estímulos fueron consistentemente menores cuando ambos estímulos estaban relacionados que cuando no lo estaban. Esto es, se encontraron efectos de priming asociativo y mediado para los estímulos relacionados.
Palabras clave: relaciones derivadas, control contextual, priming, tiempo de reacción, priming de asociación, priming mediado.

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Heretofore, much of the research into semantic relations has been conducted within the cognitive paradigm. One of the most common cognitive theories that attempts to explain aspects of semantic relations is “spreading activation theory” (e.g., Collins & Loftus, 1975). The main evidence for the nature of semantic relations in spreading activation theory comes from association priming experiments. The typical association priming experiment utilizes a lexical decision task, in which the participant is presented with two stimuli, and must decide whether both are “valid” words (i.e., if both stimuli are valid words then the participant should respond “yes”, and if one or both stimuli are not valid words then the participant should respond “no”). The first stimulus is called the “prime” and the second stimulus is called the “target”. Association priming refers to the tendency of a response time (RT) to be faster if the target is related or associated with the prime (e.g., LION-TIGER), and is thus a means of inferring the relationship between words. A variation of association priming is mediated priming, where recognition of the target is facilitated through a mediating stimulus, such as LION-STRIPES, where lion is assumed to prime the unrelated word stripes through the word tiger. The prime and target do not need to be in the same category -antonyms such a MAN-WOMAN can also prime each other (McKoon & Ratcliff, 1995). According to a popular explanation of priming effects -spreading activation theory- priming occurs because activation spreads from the prime, sometimes through mediating nodes, to the target node.

Spreading activation theory is based on the extensive research into semantic relations that has been conducted within the cognitive paradigm. However, the application of the behavior analytic concept of derived stimulus relations may provide a plausible account of priming data, and the basis for a behavioral alternative to semantic network theories more generally (e.g., Branch, 1994; Fields & Verhave, 1987). Fields and colleagues, in particular, have provided theoretical and empirical analyses of the structure of equivalence classes, and in so doing have drawn certain parallels between their work and traditional cognitive research on semantic relations. Nevertheless, there are few empirical studies in the behavioral literature that have explicitly combined the procedures typically associated with priming research and those typically found in the derived stimulus relations literature (Barnes-Holmes *et al.*, in press; Barnes-Holmes, Staunton *et al.*, 2004; Hayes & Bisset, 1998; Staunton, Barnes-Holmes, Whelan, Barnes-Holmes, Commins, Walsh, Smeets, Stewart, & Dymond, in press).

In Hayes and Bisset’s (1998) study, participants were trained, using arbitrary stimuli in match-to-sample (MTS) tasks, to establish three 3-member equivalence classes (A1-B1-C1, A2-B2-C2, A2-B2-C2) of “word-like” non-words. If the participants met the mastery criterion for the training phase they were tested for equivalence responding (i.e., matching B stimuli to C stimuli, and vice versa, in the absence of feedback). If participants reached the mastery criterion for derived relational responding during the test phase, they then proceeded to a lexical decision task. During this task participants were shown 24 pairs of equivalence class members: 8 that had been directly trained in the MTS procedure (e.g., A1 as the prime, B1 as the target), 8 related via symmetry (e.g., B1-A1), and 8 related via equivalence (e.g., B1-C1). Participants were also shown 8 pairs of stimuli that were from different equivalence classes (i.e., unrelated stimuli such as B1-C2). Response times (RTs) were significantly faster for equivalent pairs than for non-equivalent pairs. There was no significant difference in RTs among pairs composed of stimuli between which the relation had been directly trained in comparison to pairs composed of stimuli between which the relation was derived (either through symmetry or transitivity). The results of Hayes and Bissett indicated that episodic and mediated priming could be observed among derived relations, thus bolstering the notion that derived stimulus relations can serve as a useful working model of semantic meaning. Subsequently, other researchers have extended this basic effect, with larger equivalence classes (Barnes-Holmes, Staunton *et al.*, 2004; Barnes-Holmes, *et al.*, in press; Staunton, *et al.*, in press) and have also observed robust priming effects. A potential limitation of the above studies, however, is that they only studied the relation of Sameness.

The present study aims to extend the behavior analytic account of priming by examining more than one type of derived stimulus relation; specifically, the relations of Same and Opposite (Dymond & Barnes, 1996; Steele & Hayes, 1991; Whelan & Barnes-Holmes, 2004a, b).

In the present study, participants' responses to nonarbitrary stimulus relations of sameness and opposition were brought under contextual control. Participants were trained to relate physically same stimuli (e.g., a small line with a small line) in the presence of a SAME cue (in the actual experiment the cues were arbitrary stimuli, not relational words), and physically opposite stimuli (e.g., a large line with a small line) in the presence of an OPPOSITE contextual cue. Participants were then trained on a series of conditional discriminations with word-like non-word stimuli, with each discrimination being made in the presence of one of the two contextual cues. The aim of this phase was to establish responding in accordance with relations of Sameness and Opposition between the experimental stimuli (i.e., to establish A1 as the same as B1 and C1, and as opposite to B2 and C2). Participants were subsequently given a series of lexical decision tasks that included pairs of stimuli related either through Sameness or Opposition, and unrelated stimuli used as foils in the conditional discrimination training phase. The aim of the lexical decision task was to examine whether priming would occur for stimuli that participated in the relational network relative to stimuli that did not.

Method

Participants

Twelve undergraduate students between 18 and 35 years of age began the experiment. All participants were recruited through personal contacts. None of them had studied derived relations, Relational Frame Theory (RFT), or priming.

Apparatus and Setting

Participants were seated at a table in a small experimental room (2m x 2m) containing an Apple Macintosh™ Performa 640 computer with a 14-inch display.

Presentation of stimuli, participant's responses, and RTs were controlled and recorded by the computer program Psyscope (Cohen, Macwhinney, Flatt, & Provost, 1993; see also Roche, Stewart, & Barnes-Holmes, 1999). All responses were made on the computer keyboard and RTs were recorded by the Macintosh™ internal timer, which affords a minimum of 16 ms accuracy (the temporal resolution of the Macintosh™ Operating System) when measuring RTs.

Stimuli

All stimuli were in 30 point Times New Roman font. The two contextual cues were stimuli that consisted of a string of six characters (i.e., !!!!!! and ??????) and were randomly assigned to the roles of SAME and OPPOSITE cues for each participant. The stimuli in the non-arbitrary relational training phase consisted of: short, medium and long lines; small, medium, and big circles; small, medium, and big triangles; light, medium, and dark squares; few, medium, and many dots; thin, medium, and thick lines; short, medium, and tall ovals; narrow, medium, and wide ovals. It was important that the participants deem the stimuli in the MTS phase and lexical decision tasks to be words, hence stimuli were drawn from a collection of twenty-six non-words from Massaro, Venezky, and Taylor (1979, see Appendix 1) that met the following criteria: (a) they were orthographically regular; (b) they were pronounceable; (c) they contained common vowel and consonant spellings; and (d) they had no more than three letters for a medial consonant cluster if one occurred. These stimuli were randomly assigned as samples and comparison stimuli for each participant. In the interests of clarity, these stimuli are labeled using the alphanumerics; A1, B1, B2, C1, C2, N1, N2, N3, N4, X1, Y1, Y2, Y3, Y4 (participants were not exposed to these labels). All stimuli were white, and all backgrounds were black, except for the stimuli in the non-arbitrary relational training stage, which were black on a white background (it was not possible to change the colors of these stimuli in the Psyscope program).

Procedure

All participants were exposed individually to the experimental procedures. For Participants 1-4, the procedure consisted of non-arbitrary relational training and testing, arbitrary relational training, arbitrary relational testing, a battery of practice lexical decision tasks using English words, followed by a battery of lexical decision tasks using the "foreign words" and previously unseen non-word stimuli. The procedure for Participants 5-12 was similar, except that they were not exposed to an arbitrary relational testing phase, to control for the possibility that priming might occur because the stimuli were paired together in testing. In other words, the test phase may have established a direct history prior to the lexical decision task, thus potentially confounding the experiment.

Same/Opposite Non-arbitrary Relational Training and Testing

The aim of this phase was to establish functions of same and opposite for the contextual cues (!!!!!!, ??????) that were to be used in the relational training and testing phases. The instructions that were used during this phase of the experiment appeared on the computer screen (see Appendix 2).

The sample and comparison stimuli used during this phase were related to each other along a physical dimension. For example, one set of comparison stimuli in the non-arbitrary relational training stage consisted of a long line, a medium length line, and a short line. Thus, if the participant was presented with the contextual cue for opposite, and the sample stimulus was a short line, then choosing the long line was reinforced.

On all tasks, the contextual stimulus appeared in the center top third of the computer screen. The sample stimulus appeared in the middle of the screen and the three comparison stimuli appeared in a row at the bottom of the screen. The position of the comparison stimuli was counterbalanced across trials. All stimuli were presented simultaneously and remained on the screen until the participant responded by pressing one of the Z, V, or M keys, which corresponded to the left, middle, and right comparison stimuli. During the non-arbitrary relational training phases, feedback for a correct response was in the form of the printed words “Correct” or “Wrong”, presented in the center of the screen for 1.5 s. The feedback “Correct” was accompanied by a short beep from the computer. The feedback “Wrong” was not accompanied by a sound. All trials were followed by an intertrial interval of 2.5 s during both non-arbitrary relational training and testing. No feedback was presented during test phases -responses were simply followed by the intertrial interval.

The following convention is used for describing the non-arbitrary relational training and testing probes: the contextual cue is given first in capitals, followed by the sample stimulus in italics, followed by the reinforced comparison in brackets. Four tasks constituted one Problem Set (i.e., SAME/long line [long line]; SAME/short line [short line]; OPPOSITE/long line [short line]; OPPOSITE/short line, [long line]). There were eight Problem Sets in total (based on the Problem Sets employed by Steele & Hayes, 1991), each utilizing different stimuli and each consisting of four tasks.

The tasks for each Problem Set were presented in a quasi-random order in blocks of four trials with each task presented once per block. During the first non-arbitrary relational training phase participants were trained on Problem Set 1, and were then trained on Problem Set 2. The whole sequence was presented four times (i.e., 32 trials). The participant was required to respond correctly to all of the final 16 trials in order to reach the mastery criterion. If the participant did not reach the mastery criterion they were retrained on Problem Sets 1 and 2. Upon reaching the mastery criterion, the participant was exposed to the first non-arbitrary relational testing phase, which consisted of two novel problem sets. Feedback was terminated without warning. Each of the tasks from Problem Set 3 were presented in a random order until each had been presented once in a four-block trial. Following this, each of the tasks from Problem Set 4 were then presented in a random order, until each task had been presented once in a four block trial. Thus, each non-arbitrary relational testing phase consisted of eight trials. The participant was required to respond correctly on all trials during this phase in order to reach criterion. Once the participants met the mastery criterion, the non-arbitrary relational training was terminated.

Failure to meet the mastery criterion on the participant's first exposure to the first test resulted in participants being exposed to the second non-arbitrary relational training phase. In this phase, Problem Set 1 was replaced with a novel problem set (Problem Set 5). Upon reaching the mastery criterion (identical to Phase 1 non-arbitrary relational training), participants were exposed to the second non-arbitrary relational testing phase, which was similar to the first with the difference that Problem Set 3 was replaced with the novel Problem Set 6. The participant was required to respond correctly on all trials during this phase in order to reach criterion. Once the participants met the mastery criterion, the non-arbitrary relational training was terminated.

Failure to meet the mastery criterion on the participant's first exposure to the second test resulted in participants being exposed to the third non-arbitrary relational training phase. In this phase, Problem Set 2 was replaced with the novel Problem Set 7. The mastery criterion was identical to Phase 2 non-arbitrary relational training. Upon reaching criterion, participants were exposed to the third non-arbitrary relational testing phase, which was the same as the second except that Problem Set 4 was replaced with a novel problem set (Problem Set 8). Once the participants met the mastery criterion, the non-arbitrary relational testing was terminated.

Participants who did not reach the mastery criterion by non-arbitrary relational testing Test 3 did not proceed to the remainder of the experimental tasks.

Arbitrary Relational Training and Testing

Immediately following non-arbitrary relational training participants were exposed to arbitrary relational training. Because the lexical decision task required that the participants deem the stimuli to be words, participants were instructed that the stimuli were "foreign words". The instructions were as follows:

> "During this phase of the experiment you will be trained to find the relationship between foreign words, by matching some foreign words to other foreign words. All words in this phase will be TRUE foreign words.
> Look at the image at the top of the screen, then look at the foreign word in the middle of the screen, and finally look at the three foreign words at the bottom of the screen on the left, middle, and right. Choose one of the three foreign words at the bottom of the screen. You should choose one of these three words by pressing the Z, V and M keys on the keyboard in front of you. THE RELATION BETWEEN THE FOREIGN WORDS IS NOT ALREADY KNOWN TO YOU. YOU WILL HAVE TO LEARN BY TRIAL AND ERROR.
> If you want to choose the word on the left, press the Z key on the left. If you want to choose the word in the middle, press the M key in the middle. If you want to choose the word on the right, press the V key on the right.
> During some parts of the experiment you may not receive any feedback.
> If you have any questions please ask the experimenter now."

The tasks in this phase followed the same format as the tasks in the previous phase. No feedback was presented during the relational testing tasks. Participants were not informed that feedback would be terminated during this phase.

Match-to-sample probes are described using the following convention: the contextual cue is given first in capitals, followed by the sample stimulus, followed by the three comparison stimuli in brackets. The reinforced comparison is in *italics.* For example the notation SAME/A1-[*B1*-B2-N1] indicates that in the presence of the contextual cue SAME and the sample stimulus A1, selecting B1 was reinforced.

Participants were presented with the following training tasks; SAME/A1-[*B1*-B2-N1), SAME/A1[*C1*-C2-N2], OPPOSITE/A1-[B1-*B2*-N1], OPPOSITE/A1-[C1-*C2*-N2], SAME/X1-[*Y1* -B1-N3], SAME/X1[*Y2* -C1-N4], OPPOSITE/X1-[*Y3* -B2-N3], OPPOSITE/X1-[*Y4* -C2-N4]. The latter four training tasks were included so as to ensure that choosing B1 and C1 in the presence of SAME, and choosing B2 and C2 in the presence of OPPOSITE would be reinforced on some trials, but not on others. This pattern of reinforcement was included to control for the possibility that SAME and OPPOSITE cues might simply function as mediating nodes for simple equivalence relations between B1 and C1, and between B2 and C2 respectively (see Dymond & Barnes 1996, for a detailed discussion of this issue). Note that no reinforcement was given for choosing the N1, N2, N3, and N4 comparison stimuli.

Training occurred in blocks of 80 trials, with each of the eight tasks presented 10 times in a quasi-random order. The participants were required to choose the correct comparison at least nine times across 10 exposures to each task to reach criterion on the relational training phase. The relational network that was established is displayed in Figure 1. Note that from the four directly trained relations, four mutually entailed and four combinatorially entailed relations may be derived.

When Participants 1-4 met the criterion on the relational training phase they were exposed to the arbitrary relational testing phase, the aim of which was to examine if responding in accordance with the derived relations of sameness and opposition would emerge. The test tasks were as follows; SAME/B1-[C1-C2-N2]; SAME/B2[C1-C2-N2]; OPPOSITE/B1-[C1-C2-N2]; OPPOSITE/B2-[C1-C2-N2] (X, Y, N3, and N4 were not presented to the participants during relational testing). It was expected that participants would (i) choose C1 given B1 in the presence of same (B1 and C1 are both the same as A1 and therefore the same as each other); (ii) choose C2 given B2 in the presence of same (B2 and C2 are both opposite to A1 and therefore the same as each other); (iii) choose C2 given B1 in the presence of opposite (B1 is the same as A1, and C2 is opposite to A1, and therefore B1 is opposite of to C2); and (iv) choose C1 given B2 in the presence of opposite (B2 is opposite to A1, and C1 is the same as A1, and therefore B2 is opposite to C1). Testing occurred across blocks of 40 trials with each of the four tasks presented 10 times in a quasi-random order. If participants did not demonstrate the predicted performance on 9 of 10 trials for each task, they were re-exposed to the arbitrary relational training and testing sequence up to a maximum of six times.

Lexical Decision Tasks

The lexical decision tasks commenced immediately after the completion of the

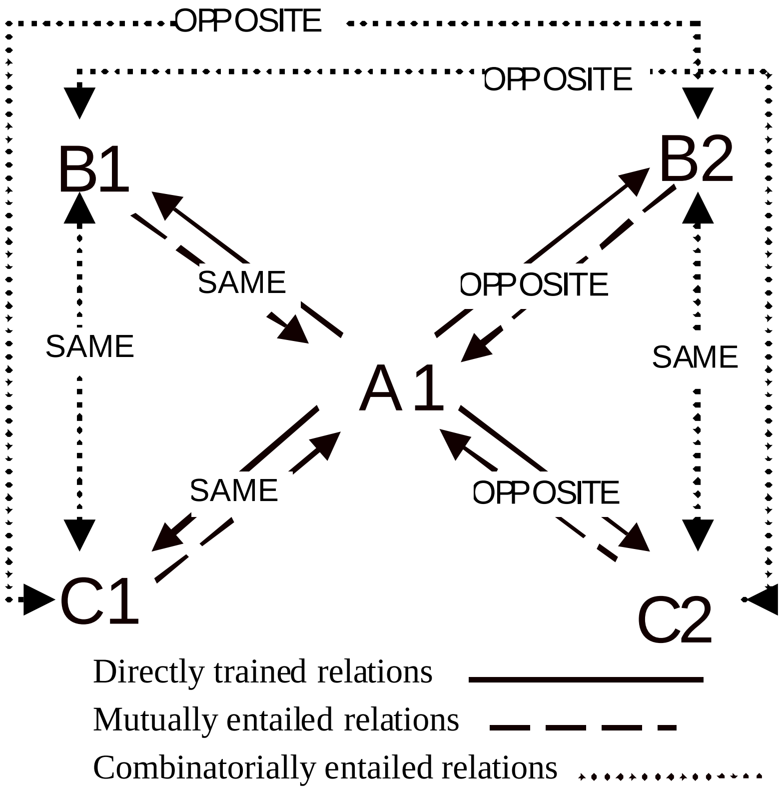

Figure 1. Diagrammatic representation of the relational network.

arbitrary relational training (and testing where applicable). The procedure was similar to that employed by Meyer and Schvaneveldt (1971). At the beginning of each trial, the word “Ready” was presented on the screen for 3 s as a warning signal. At the bottom of the screen was the instruction “Work as fast as you can without making mistakes”. Following this, two stimuli were displayed in the middle of the screen, with one string of letters centered above the other. At the bottom of the screen was the question “Are both of these foreign words?”. If both of the stimuli were foreign words (i.e., all the stimuli that the participant had been exposed to in the arbitrary relational training phase, including incorrect comparison stimuli), the correct response was to press the “Y” key. If one or both of the stimuli was not a foreign word (i.e., a previously unseen stimulus) the correct response was to press the “N” key. Response time was measured from the stimulus-onset to the response, which terminated the stimulus display. Feedback was in the form of the words “Correct” or “Wrong” appearing in the middle of the screen for 2 s immediately following their response. The contextual cues were not presented during this phase.

Prior to testing with the pretrained stimuli, the participants had a practice session

Table 1. Pairs of related stimuli shown to participants.

Relation	Prime	Target
Directly trained Same	A1	B1
	A1	C1
Directly trained Opposite	A1	B2
	A1	C2
Mutually entailed Same relation	B1	A1
	C1	A1
Mutually entailed Opposite relation	B2	A1
	C2	A1
Combinatorially entailed Same relation	B1	C1
	B2	C2
Combinatorially entailed Opposite relation	C2	B1
	B2	C1

with English words, where they were exposed to 24 pairs of stimuli. Twelve of the pairs were composed of two English words, the correct response being "Yes"; six pairs consisted of one English word and one novel non-word (these non-word stimuli were also taken from Massaro et al., 1979, see Appendix 1, p. 30), the correct response being "No"; and six pairs were both non-words, the correct response being "No" (the instructions for the practice session are in Appendix 3, p. 32).

Immediately following the practice session, the participants were exposed to the lexical decision tasks. The following instructions appeared on the screen:

> "Now that you have had some practice, let's begin using foreign words and non-words. During this phase of the experiment, you will be asked to respond to some words on the computer screen; some of these words will be the foreign words you have just learned. However, some of the words will be nonsense words.
> Two words will appear on the screen, one below the other. You will be asked: 'are both of these foreign words?' Your task will be to hit the 'Y' key (for yes), if they are BOTH foreign words and the 'N' key (for no), if one or both are not foreign words."

Participants were shown 12 pairs of related stimuli (see Table 1). Participants were also shown five pairs of unrelated stimuli ("Control pairs") using N, Y, and X stimuli from the relational training tasks (e.g., A1-N1, C2-N4, B2-Y1 etc.). Participants were also shown five pairs composed of stimuli involving a relational network member and a novel non-word, and six pairs of non-words. Thus for 12 stimulus pairs the correct response was "Yes" and for 16 stimulus pairs the correct response was "No".

Following completion of the lexical decision task, participants were thanked for their participation and fully debriefed.

Results

The results of Participants 10 and 11 are not included because they did not reach the mastery criterion for the non-arbitrary relational training. The results of Participant

12 are not included because it transpired that the participant had read the instructions for the lexical decision task incorrectly. Participants 1-9 reached the criterion for the non-arbitrary relational training stage, requiring a maximum of two exposures to the training and testing phases. Participants 1 and 2 and Participants 5-9 reached the criterion on the arbitrary relational training phase, requiring between two and five blocks of 80 training trials, and subsequently completed the lexical decision tasks. Participants 3 and 4 did not reach the mastery criterion for the arbitrary relational testing stage after exposure to six blocks of 80 training trials, and subsequently completed the lexical decision tasks.

In the following results section it is important to note the specific comparisons among trial types, in order to examine whether association and mediated priming occurred due to derived stimulus relations, rather than other factors. "Related Pairs" refers to pairs of stimuli connected through the relations of Sameness and Opposition that were established in the relational training phase. The "Control Pairs" were pairs of stimuli composed of one foreign word from the relational network and one foreign word that the participant had been exposed to earlier in the conditional discrimination training phase, but that did not enter into the relational network, providing a control for the possibility that priming occurred solely because some stimuli were all classed as "foreign words". In other words, the important comparisons are among pairs of previously seen words.

Individual Data

Table 2 displays the mean RTs of all correct responses for related and control pairs for Participants 1-9. Participants 1-4 were exposed to formal tests for derived relations. Participants 1 and 2 both passed the arbitrary relational test, and their mean RTs for the Related Pairs are lower than the mean RTs for the Control Pairs, which is indicative of priming. Participants 3 and 4 did not reach the mastery criterion for the arbitrary relational training. There was little difference between the mean RT for related

Table 2. Data for individual participants in the lexical decision task.

Participant	Mean response time	
	Related pairs	Control pairs
1[a]	616	828
2[a]	627	845
3[a,b]	1163	1130
4[a,b]	692	634
5	852	917
6	888	1397
7	759	1056
8	743	980
9	800	891

aExposed to the arbitrary relational test.
bFailed the arbitrary relational test.

pairs relative to the mean RT for control pairs for Participants 3 and 4. Participants 5-9 reached the mastery criterion for arbitrary relational training (i.e., 90% correct for the last training block), but were not exposed to formal tests (MTS probes) of derived relations. In all cases the mean RT for the related pairs were lower than the mean RT for the control pairs, indicating that priming occurred.

Mean Data

Participants 1 and 2 were exposed to the arbitrary relational test, and therefore their results are not included in the mean data, nor were the data from Participants 3 and 4, who failed the arbitrary relational test. Response latencies over 2 s were removed as outliers (4% of valid data points). The mean across-participants RT for Participants 5-9 was 805 ms (standard error of the mean [SEM]= 25 ms) for related pairs and 1049 ms (SEM= 68 ms) for control pairs. The moderately high SE for control pairs may be a consequence of the few data that were collected (compared to cognitive studies). This was due to the high error rate for control pairs, which reduced the number of valid RTs. Thus, some caution should be exercised when interpreting the results.

Figure 2 shows the mean across-participants RT and SEM for Participants 5-9. Each column represents the history of the relation between the two words presented together in the lexical decision task. Note that the contextual cue was not presented during the lexical decision task, but nevertheless the history of the relation is either one of sameness or opposition. All responses to Related Pairs (whether directly trained,

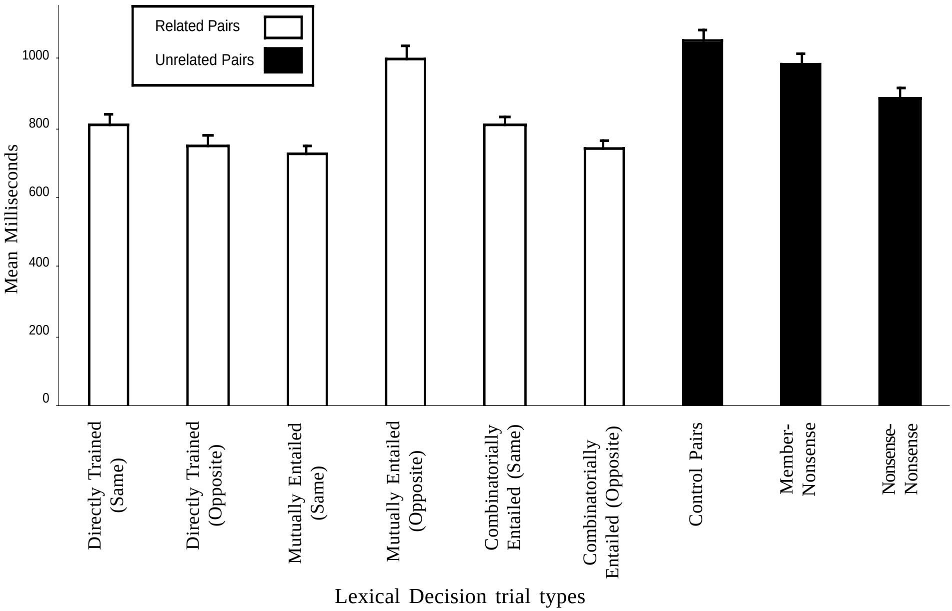

Figure 2. The mean reaction time (+SEM) of all correct responses for related and control pairs for Participants 5-9 in the lexical decision task. Priming is indicated by the lower reaction time for the related pairs relative to the unrelated pairs.

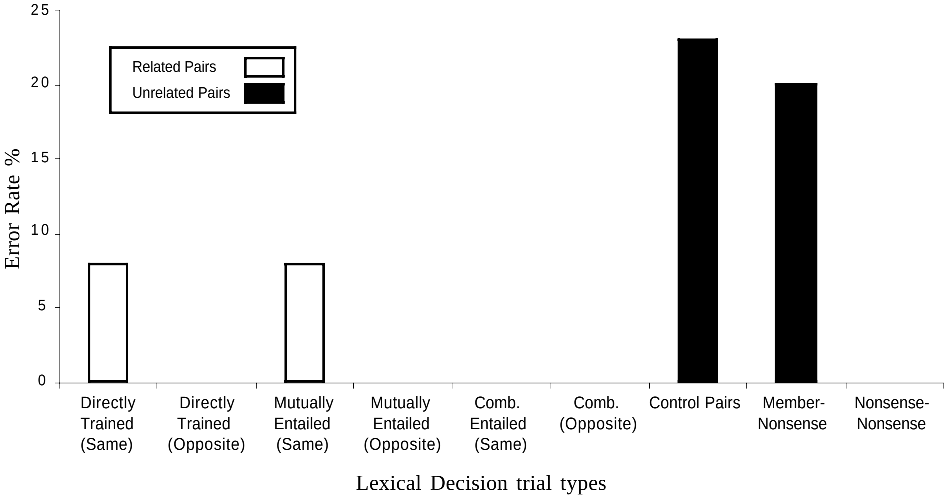

Figure 3. The mean percentage of errors within each trial type for related and unrelated pairs for Participants 1-7 in the lexical decision task. Priming is indicated by the higher error rate for unrelated pairs relative to the related pairs.

mutually entailed, or combinatorially entailed, or related through sameness or opposition) were faster relative to Control Pairs, suggesting that priming occurred.

Figure 3 displays the across-participants mean percent error rate per trial type. The highest error rate occurred for pairs of control stimuli; that is, when the participant responded incorrectly, reporting that both words were not foreign words.

To test if RTs were significantly different across trial types, Wilcoxon Signed-Rank tests were conducted. Table 3 displays the results of the planned comparisons.

Correct responses were significantly faster for all related pairs than for control

Table 3. Results of Wilcoxon Signed-Rank tests comparing RT among different trial types in the lexical decision task.

Comparison Number	TRIAL TYPE	Significance Level (2-Tailed)
1	Control vs. all related pairs	.046
2	Control vs. all directly trained	.046
3	Control vs. all mutually entailed	.039
4	Control vs. all combinatorially entailed	.005
5	Directly trained vs. all combinatorially entailed	.981
6	Directly trained vs. all mutually entailed	.277
7	Mutually entailed vs. all combinatorially entailed	.210
8	All related Same vs. all related Opposite	.589
9	Directly trained Same vs. directly trained Opposite	.515
10	Mutually entailed Same vs. mutually entailed Opposite	.021
11	Combinatorially entailed same vs. combinatorially entailed Opposite	.327

pairs (Comparison 1). Correct responses were also significantly faster, in comparison to control pairs, for each type of training history; that is, whether directly trained, mutually entailed, or combinatorially entailed (Comparisons 2, 3, and 4). The mean across-participants RT did not differ significantly by training history (Comparisons 5, 6 and 7). A comparison of correct RTs between responses to pairs of stimulus related through Same and Opposite indicates no significant difference between RTs to Same and Opposite relations (Comparison 8). Analyzing this further, RTs to lexical decisions where both stimuli were paired together in training did not differ significantly by relation (Comparison 9), nor did they differ by relation when both stimuli were combinatorially entailed (Comparison 11). However, RTs to lexical decisions where both stimuli were mutually entailed did differ significantly by relation (Comparison 10).

In conclusion, the results reported in the present study are indicative that priming occurred due to previous exposure to the arbitrary relational training tasks, because the mean RT for related pairs was significantly lower than the mean RT for control pairs. The results also indicate that priming can be demonstrated through both directly trained and derived stimulus relations. Two participants (3 and 4) who did not reach criterion but who subsequently completed the lexical decision task did not demonstrate priming, despite more exposure to the experimental stimuli.

Discussion

All participants who reached criterion in the arbitrary relational training phase subsequently demonstrated both association (e.g., B1‡A1) and mediated priming (e.g., B1‡C2) in a lexical decision task. Because the training history of the stimuli in the lexical decision task was controlled, the present study demonstrated that the priming effects were dependent upon that specific history. Hence, the present research also demonstrated episodic priming; that is, stimuli that were not pre-experimentally associated became associated during the course of training in the experiment. Generating priming by using novel procedures lends credence to the existence of the priming phenomenon per se, but more importantly the present study lends credence to an etiology of priming from a behavior analytic perspective, and affords comparisons with cognitively orientated studies. Evidence for the potency of this explanation was demonstrated in that priming occurred not only for pairs of stimuli between which there was a direct discriminative relation, but also for stimuli between which there was a derived relation. Furthermore, priming occurred for pairs of stimuli that were related either through the relations of Same or Opposite. Thus, the present work extends the findings of Hayes and Bisset (1998), who employed only equivalence relations in their research.

The present study has provided evidence in support of the claim that priming is a specific example of the transformation of stimulus functions, either through directly trained or derived relations. Heretofore, in behavior analytic studies, testing for derived relations and the transformation of stimulus functions through those relations has usually been by means of percentage of test trials correct in MTS probes (Barnes-Holmes, Barnes-Holmes, Smeets, Cullinan, & Leader, 2004). Dymond and Rehfeldt (2001) have suggested that, in addition to MTS probes, other methods of testing for derived stimulus relations should be considered, because over reliance on the MTS procedure may “preclude important discoveries regarding the nature of derived stimulus relations” (p.8). In particular, participants’ responses to related stimuli may vary along a temporal dimension even when response accuracy has stabilized (Spencer and Chase, 1996). Furthermore, Participants 3 and 4, who were both exposed to 480 relational training trials (the maximum allowed), did not display the expected pattern of responding during emergent relations probes. Participant 3 responded correctly on 69% of the final block of testing trials, and Participant 4 responded correctly on 72.5% of the final block of testing trials. It can be inferred from this pattern of responding that neither Participant 3 nor Participant 4 was responding in accordance with the experimenter-designated relational network. However, although both participants had more exposure to the experimental stimuli than any of the other participants who reached criterion, they did not demonstrate responding consistent with priming in the lexical decision task. The data from Participants 5-9 indicate that the lexical decision methodology is sensitive to derived stimulus relations. However, Participants 5-9 did not receive formal tests of derived relations, and thus it is not known if these participants would have subsequently passed an MTS task. Previous studies (e.g., Whelan & Barnes-Holmes, 2004a) have typically reported several failures on tests of derived Same and Opposite responding. Therefore, future studies should consider including formal tests of derived relation after the lexical decision task. Nonetheless, perhaps priming could provide behavior analysis with a useful test for the transformation of functions through derived stimulus relations.

The reader may note that the contextual cues were not presented in the lexical decision task. However, priming experiments in the cognitive tradition do not present the word that represents the relation obtained between the two stimuli in a lexical decision task (e.g., the word “Opposite” is not presented; McKoon & Ratcliff, 1995). In these experiments, for example, word-pairs such as HOT-COLD and MAN-WOMAN are presented. These word pairs are expected to prime each other relative to word pairs such as HOT-DOOR or MAN-CEILING.

The lexical decision task in the present experiment incorporated feedback (Hayes & Bissett, 1998; Meyer & Schvaneveldt, 1971; cf. Barnes-Holmes, Staunton et al., 2004; Staunton et al., in press), the words Correct and Wrong were presented after correct and wrong responses, respectively. Presenting feedback during the lexical decision task might introduce an inconsistency between the feedback presented during the conditional discrimination training and the lexical decision task. That is, during the conditional discrimination training, matching stimuli from the same to-be-established equivalence relations was consequated with “Correct”, and matching stimuli from different relations was consequated with “Wrong”. However, during the lexical decision task, responding YES to both equivalent and non-equivalent stimulus pairs was consequated with “Correct”. Insofar as participants treated YES and “Correct” as functionally equivalent, the feedback presented during the lexical decision task would have appeared to contradict the feedback presented during the conditional discrimination training (e.g., A1-B2 was wrong during MTS training but correct during the priming task). In the present study, the highest number of errors (23% across Participants 5-9) occurred for the Class-

Nonclass priming trial type and was 35% in Hayes and Bissett (1998). In contrast, error rates for Staunton et al. (in press) study, in which no feedback was provided during the lexical decision task, were similar across all trial types.

An unexpected result reported in the present experiment was that RTs to pairs of stimuli related through mutually entailed Same relations were significantly faster than RTs to pairs of stimuli related through mutually entailed Opposite relations. This is unexpected because neither Same nor Opposite relations give rise to novel relations at the level of mutual entailment (i.e., if A Same as B, then B Same as A is entailed; if A Opposite to B, then B Opposite to A is entailed). In contrast, two Same relations combine to entail yet another Same relation (e.g., A Same as B and B Same as C entails C Same as A), two Opposite relations combine to entail a Same relation (i.e., A Opposite to B and B Opposite to C entails C Same as A). Thus, RTs to mutually entailed pairs are predicted to be similar if the relations are ones of sameness or of opposition (O'Hora, Barnes-Holmes, Roche, & Smeets, 2002; Steele & Hayes, 1991). It is not clear at the present time why this was not the case in the present study.

The present study did not find any significant differences in RT based on the number of nodes between pairs of stimuli in the lexical decision task; that is, between pairs of stimuli not connected through an intervening node (directly trained and mutually entailed pairs) and pairs connected through one intervening node (combinatorially entailed). Hayes and Bisset (1998) also reported that mean RT did not differ significantly by the number of nodes. However, other behavior analytic studies that measured RT as a function of derived relations using MTS probes (e.g., Fields, Adams, Verhave, & Newman, 1990; Steele and Hayes, 1991; Wulfert & Hayes, 1988) have indicated that, as the number of nodes between the sample and comparison stimuli increases, so does RT (e.g., RTs to mutual entailment probes are faster than to probes of combinatorial entailment). In examining the incongruity in RT between studies that examined derived relations in lexical decision tasks and those studies that used MTS test probes, it is possibly worth noting that none of the experiments using MTS probes gave instructions to the participants as to whether they should work quickly or not. In addition, Imam (2001), employing a single participant design, suggested that unbalanced numbers of baseline training trials may have confounded previous studies that reported nodality effects. Perhaps future priming research could investigate whether differential RTs would emerge as a function of nodal distance in networks that contain more than one node, as was the case in both the present study and that of Hayes and Bisset (1988).

The present study has clear overlap with semantic network theories of lexical processes and structures (e.g., Collins & Loftus, 1975), in which concepts are represented by the nodes of a network linked with various strengths to other concepts/nodes. While the majority of research into semantic network theory has focused on characterising the structure of existing networks, the process by which new concepts enter the network, and become linked to other concepts/nodes has received relatively little attention. Recent models of semantic network growth suggests that semantic structures primarily grow when connections are established between new nodes and existing nodes (Steyvers & Tenenbaum, 2005). These models place particular emphasis on stimulus frequency and time of acquisition -higher frequency and earlier acquisition result in more robust connections. However, the role of reinforcement has been neglected in these models, perhaps due to the common misconception that behavior analysis is only concerned with direct contingencies and therefore has little to contribute to theories of human language (e.g., Tomasello, Carpenter, Call, Behne, & Moll, 2005, p. 721). Behavior analysts who study derived stimulus relations have the potential to contribute to semantic network theory, and cognitive psychology more generally (Reilly, Whelan, & Barnes-Holmes, 2005), perhaps beginning a rapprochement between behavioral and cognitive psychologies.

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Appendix I: Stimuli from Massaro, Venezky and Taylor (1979).

BETRET	RIGUND
BOCEEM	RONKEB
CASORS	SAMOLT
CIPHER	SIFLET
DRAGER	SINALD
HAVEEN	SURTEL
HEITER	TROPER
LEWOLY	VARTLE
LORALD	WOLLEF
MATSER	WRONED
MURBEN	CACHEN
REMOND	DESUND
RETTES	GEDEER

Appendix II: for instructions the Same/Opposite non-arbitrary relational training and testing phase.

In a moment some images will appear on this screen. Your task is to look at the image at the top of the screen, then look at the image in the middle of the screen and finally look at the three images at the bottom of the screen on the left middle and right. Your task is to choose one of the three images at the bottom of the screen. You should choose one of these three images by pressing the Z, V, or M key on the keyboard in front of you.

If you want to choose the image on the left, press the Z key on the left. If you want to choose the image in the middle, press the M key in the middle. If you want to choose the image on the right, press the V key on the right.
During some parts of the experiment you may not receive any feedback.
If you have any questions please ask the experimenter now.

Appendix III: Instructions from the practice lexical decision task.

During this phase of the experiment, you will be asked to respond to some words on the computer screen; some of these words will be English words and some of the words will be non-words.

Two words will appear on the screen, one below the next. You will be asked: ‘are both of these English words?’ Your task will be to hit the ‘y’ key (for yes), if they are BOTH English words and the ‘n’ key (for no), if one or both are not English words.
YOU SHOULD WORK AS FAST AS YOU CAN WITHOUT MAKING MISTAKES.
If you have any questions please ask the experimenter now.