International Journal of Psychology and Psychological Therapy 2004, Vol. 4, Nº 2, pp. 285-302

Empirical Models of Formative Augmenting in Accordance with the Relations of Same, Opposite, More-than and Less-than

Robert Whelan* **and Dermot Barnes-Holmes**

National University of Ireland, Maynooth, Ireland

Abstract

In the Relational Frame Theory literature, the term "formative augmenting" is used to describe transformations of function that establish particular consequences as either reinforcers or as punishers. This type of behavior is important because derived consequential stimuli may control behavior in the absence of direct training. The experiments described here are laboratory models of formative augmenting, in accordance with the relations of *Same*, *Opposite*, *More-than* and *Less-than*. In the first experiment, a member of a relational network seemed to acquire reinforcing functions, based on the derived relations of Same and Opposite, although no such function had actually been established for any member of that network. In the second experiment, the consequential functions of stimuli were manipulated in accordance with the relations of *More-than* and *Less-than*. In a subsequent operant task, subjects consistently emitted the response that produced the higher-ranked consequential stimulus, thus demonstrating a transformation of consequential functions.
Key Words: Formative augmenting, derived consequential stimuli, establishing operations, motivation, RFT.

Resumen

En la literatura de la Teoría del Marco Relacional, el término "augmenting" formativo se emplea para describir transformaciones de funciones determinan el establecimiento de ciertas consecuencias como reforzadores o eventos aversivos. Este tipo de conducta es importante porque los estímulos (eventos) consecuentes derivados pueden ejercer control conductual en ausencia de un entrenamiento directo para ello. Los experimentos que se describen en este trabajo son modelos de laboratorio del augmenting formativo, de acuerdo con las relaciones de *Igualdad*, *Oposición*, *Más que-* y *Menos que-*. En el primer experimento se observa la adquisición de funciones reforzantes por parte de un miembro de una red relacional, sobre la base de relaciones de Igualdad y Oposición, aunque esa función no se había establecido de manera directa para ningún miembro de la red relacional. En el segundo experimento, las funciones consecuentes de los estímulos se manipularon de acuerdo con las relaciones de *Más que-* y *Menos que-*. Posteriormente, al ejecutar una tarea operante los participantes emitieron de manera consistente la respuesta que producía el estímulo consecuente de mayor valor reforzante de acuerdo con las relaciones previa-

* Research for this paper was funded by the Irish Research Council for the Humanities and the Social Sciences, through a Government of Ireland Scholarship. The research was conducted as part of Robert Whelan's doctoral research program, under the supervision of Dermot Barnes-Holmes. Correspondence should be addressed to Robert Whelan at the Department of Psychology, National University of Ireland Maynooth, Maynooth, Co. Kildare, Ireland. (E-mail: Robert.a.whelan@may.ie).

mente establecidas, lo que muestra una transformación de funciones consecuentes.
Palabras clave: Augmenting formativo, funciones consecuentes, establecimiento de operaciones, motivación, RFT.

A fundamental tenet of behavior analysis is that responses are more or less probable because of the consequences that they produce. Consequential stimuli that occur contingent on a behavior and increase response probability are termed reinforcers. The effectiveness of stimuli that result from contingent pairings with other reinforcers (i.e., conditioned reinforcers), are particularly pertinent to the establishment and maintenance of human behavior. According to Skinner (1953), temporal gaps between responses and an ultimate, unconditioned, reinforcer are bridged by intervening conditioned reinforcers. Furthermore, "among the conditioned reinforcers responsible for the strength of [this] behavior are certain verbal consequences…" (1953, p.77). Modeling the effect of "verbal" conditioned reinforcers in the behavioral laboratory could have far-reaching implications for our understanding of how behavior in the natural environment can come under the control of consequences that have not been directly paired with primary reinforcers or punishers.

From the perspective of Relational Frame Theory, the term "formative augmenting" is used to describe derived transformations of function that establish particular consequences as either reinforcers or as punishers (see Barnes-Holmes, O'Hora, Roche, Hayes, Bisset, & Lyddy, 2001). For example, if a person was given a number of plastic disks and told, "these plastic disks worth are € 20", and the disks now function for the first time as reinforcers, the statement was a formative augmental. Thus, formative augmentals can contribute to behavioral regulation even if the "new consequences" are never actually contacted.

Hayes, Kohlenberg, and Hayes (1991) examined formative augmenting in accordance with equivalence relations, demonstrating that consequential functions given to one member of an equivalence class transferred to other members of that class. The basic procedure was as follows. The B1 stimulus was established as a conditioned reinforcer, and the B3 stimulus was established as a conditioned punisher. Subjects were then exposed to conditional discrimination training (A-B then A-C) and subsequent testing for symmetry and equivalence responding. Upon reaching criterion on these probe trials, subjects were exposed to a test for formative augmenting where the C1 and C3 stimuli were used as differential consequences in a sorting task. Eight of nine subjects exposed to this procedure demonstrated the predicted transfer of consequential control from the B to the C stimuli.

Since Hayes et al.'s research, several studies have provided empirical evidence that it is possible for human subjects to respond in accordance with relations other than equivalence, including; Same, Opposite, and Different (Dymond & Barnes, 1996; Roche & Barnes, 1996, 1997; Roche, Barnes-Holmes, Smeets, Barnes-Holmes, & McGeady, 2000; Steele & Hayes, 1991; Whelan, 2002), More-than and Less-than (Dymond & Barnes, 1995; O'Hora, Barnes-Holmes, Roche, & Smeets, 2002; see also Barnes-Holmes, Barnes-Holmes, Roche, Healy, Lyddy, Cullinan, & Hayes, 2001), and Before and After (Barnes-Holmes, Hayes, Dymond & O'Hora, 2001). Given the important role that consequences play in shaping and maintaining behavior, the investigation of formative augmenting in accordance with multiple stimulus relations seems to be necessary if we are to explain complex human behaviors. The current article reviews two studies that sought to model some of the ways in which multiple stimulus relations may participate in the establishment, and maintenance of, reinforcers in verballyable humans.

The first experiment outlined in the current article examined formative augmenting in accordance with Same and Opposite relations. A stimulus, B2, was first established as a conditioned punisher, using direct stimulus pairing. The next stage involved nonarbitrary relational training, designed to establish SAME and OPPOSITE contextual cues. Subsequently, subjects were exposed to arbitrary relational training, using these contextual cues to establish A1 as the same as B1 and C1, and as opposite to B2 and C2. In the test for formative augmenting, three stimuli (C1, C2, and an unrelated stimulus) were presented in the transformation of consequential functions test. Subjects were expected to choose the stimulus that produced C1 as a consequence, because C1 participated in a frame of Opposition with B2, which had been paired with punishment.

The second experiment described here analyzed formative augmenting in accordance with a linear ranking relational network (described here with sequential, alphabetical characters ABCDEFG). In the first phase, contextual cues for More-than and Less-than were established. Subjects were then trained in six conditional discriminations; A<B, B<C, C<D, E>D, F>E and G>F; with the contextual cues as sample stimuli and two three-letter nonsense words as comparison stimuli. All possible derived or untaught relations were then tested (e.g., B<F). Next, in a stimulus-pairing procedure, the "D" stimulus, from the relational network, was established as a CS+. Finally, a test for transformation of consequential functions was presented in which subjects were required to emit one of two responses, each of which produced a particular element from the relational network. It was predicted that subjects would consistently emit the response that produced the consequential stimulus that was ranked higher in the relational network. Also, the baseline conditional discriminations were altered across an ABA reversal design, and it was predicted that the consequential functions of the relational network members would be appropriately transformed.

General method

Subjects

Eight subjects (age range 17-22) began the experiments, and were recruited either through personal contacts or notice-board advertisements. Subjects in Experiment 1 were paid € 40, and subjects in Experiment 2 were paid € 20, contingent on completing the experiment. Subjects 1, 3, 4, 7 and 8 were undergraduate students in disciplines other than psychology, Subject 2 was a postgraduate student in a discipline other than psychology, and Subjects 5 and 6 were psychology undergraduates. Subjects 1-6 were naïve, however Subjects 7 and 8 had recently completed a similar experiment, but neither had been debriefed following the earlier experiment. None of the subjects had prior knowledge of Relational Frame Theory, or the stimulus equivalence literature more generally.

Apparatus and Setting

Subjects were seated at a table in an experimental room containing an Apple Macintosh™ iBook computer with a 12.1 in. display. Presentation of stimuli, subject's responses, and response times 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 by moving and clicking a Macintosh™ optical mouse.

Experiment 1: Formative augmenting in accordance with the relations of same and opposite

Procedure

Phase 1: Establishing Consequential Functions. The aim of this phase was to establish, and test for, the consequential functions of two arbitrary shapes (B2 and X1). Phase 1 was composed of four blocks, each block consisting of six trials of stimulus pairing followed by eight trials of simultaneous discrimination probe trials. The stimulus-pairing procedure involved pairing B2 with the loss of points and X1 with the gain of points. Immediately following the six trials of stimulus pairing, subjects were exposed to eight simultaneous discrimination probe trials that used B2 and X1 as differential consequences. On the bottom left and the bottom right of the screen there were two three-letter nonsense words: these positions were counterbalanced randomly across trials. Clicking on one of the nonsense words was consequated with the B2 stimulus, which appeared in the middle of the screen for 2 s. Similarly, clicking on the other nonsense word produced X1 as a consequence. The aim of these simultaneous discrimination probe trials was to determine whether B2 and X1 had become effective as punishers and reinforcers, respectively, based on their prior pairing with point loss and point gain. In order to reach criterion for this phase, subjects were required to chose the stimulus that produced X1 across at least the final 10 trials of the simultaneous discrimination task before proceeding to Phase 2.

Phase 2: Nonarbitrary Relational Training and Testing. The aim of this phase was to establish the functions of SAME and OPPOSITE for the contextual cues that were to be used in the arbitrary relational training and testing phases (Phase 3). The contextual cues were arbitrary shapes, but the sample and comparison stimuli used during Phase 2 were related to each other along a physical dimension. For example, one set of stimuli in this phase consisted of a long line, a medium-length line, and a short line. Thus, if the subject was presented with the contextual cue for OPPOSITE, and the sample stimulus was a short line, then choosing the long line was reinforced; if the subject was presented with the contextual cue for SAME, and the sample stimulus was a short line, then choosing the short line was reinforced. The other sets of arbitrary stimuli in the Phase 2 consisted of: light, medium, and dark squares; six sets of three arbitrary geometric shapes that, within sets, were either small, medium or large in size; and two sets of stimuli derived from clipart pictures enclosed by a rectangular border (one, three, and six ducks; small, medium, and large pencils).

The following convention is used for describing the nonarbitrary relational training and testing probes: the contextual cue is given first in capitals, followed by the sample stimulus in italics, followed by the experimenter-designated correct comparison in brackets.

Each set of nonarbitrary stimuli was used to generate four tasks (i.e., SAME/*long line* [long line]; SAME/*short line* [short line]; OPPOSITE/*long line* [short line]; OPPOSITE/*short line*, [long line]). Each nonarbitrary relational test consisted of 10 trials. Feedback was terminated without warning at the beginning of the nonarbitrary relational test. If a subject responded correctly across all 10 trials, Phase 2 was terminated. Failure to meet this criterion resulted in re-exposure to further nonarbitrary relational training.

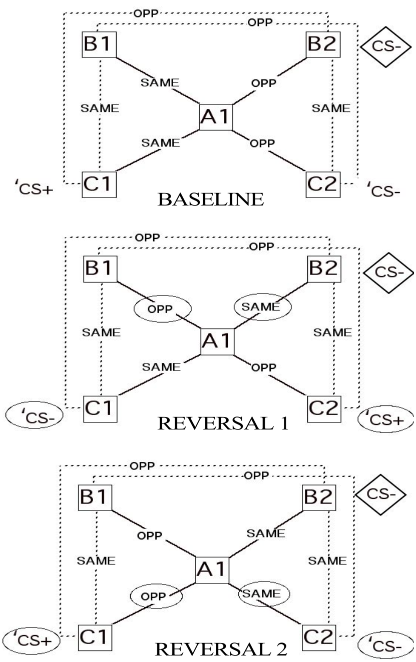

Figure 1. Overview of the procedure for Subjects 1-4, displaying the trained and tested relational networks across the Baseline, Reversal 1, and Reversal 2 conditions.

Phase 3: Arbitrary Relational Training and Testing. Immediately following Phase 2, subjects were exposed to arbitrary relational training. The aim of this phase was to establish a relational network in which the arbitrary stimuli B1 and C1 were the same as A1, and B2 and C2 were opposite to A1 (see Figure 1, top panel). The contextual cues were the same as those used in Phase 2. All sample and comparison stimuli used in the relational training phase were novel arbitrary geometric shapes, with the exception of A1, which had been presented in Phase 1. Different stimuli were used as samples or as comparison stimuli for each subject.

The most important trials types were as follows: SAME/A1-B1, SAME/A1-C1, OPPOSITE/A1-B2, and OPPOSITE/A1-C2. Training occurred in blocks of eight trials, with each of eight trial types presented once per block. The subjects were required to choose the correct comparison across 10 consecutive trials before being exposed to arbitrary relational testing.

The aim of arbitrary relational testing was to determine if responding in accordance with the derived relations of sameness and opposition would emerge during non-reinforced MTS probes. The test trial types were as follows; SAME/B1-C1; SAME/B2-C2; OPPOSITE/B1-C2; OPPOSITE/B2-C1. Responding in accordance with the predicted relational network required that subjects would (i) choose B1 given C1 in the presence of SAME (B1 and C1 are both the same as A1 and therefore the same as each other); (ii) choose B2 given C2 in the presence of SAME (B2 and C2 are both opposite to A1 and therefore the same as each other); (iii) choose B1 given C2 in the presence of OPPOSITE (B1 is the same as A1, and C2 is opposite to A1, and therefore B1 is opposite to C2); and (iv) choose B2 given C1 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 in a block of 16 trials, with each of the four tasks presented four times in quasi-random order. If a subject did not demonstrate the predicted performance on all of the trials for each trial type, they were re-exposed to Phase 3.

Phase 4: Test for Transformation of Consequential Functions. Phase 4 was broadly similar to Phase 1 in that it contained both simultaneous discrimination and stimulus-pairing trials. The following instructions were presented to subjects at the beginning of Phase 4:

> "*Your task during this phase of the experiment is to earn as many points as possible. You will have to make your best guess about what is the right thing to do to earn maximum points*".

As in Phase 1, B2 was paired with point loss, and X1 with point gain. In this phase, subjects were presented with a total of 32 simultaneous discrimination probe trials, interpolated with 8 stimulus-pairing trials. Three consequential stimuli were used in the test for transformation of consequential functions: C1, C2, and an unrelated stimulus. A transformation of functions in accordance with the relational network predicts that subjects should demonstrate a preference for the stimulus that produces C1 as a consequence, rather C2, because the former stimuli participate in a frame of Opposition

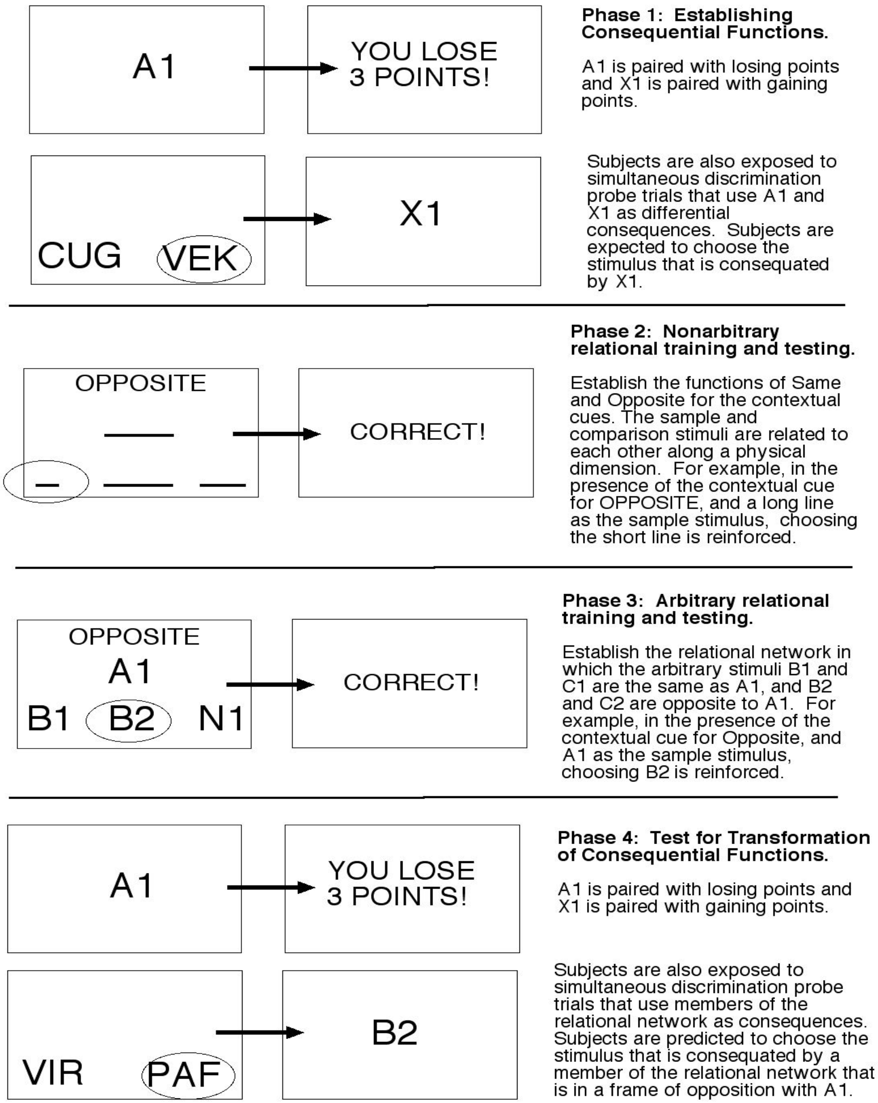

Figure 2. Diagrammatic representations and brief descriptions of the typical experimental tasks that were presented during the four phases. The figures on the left are representative of the tasks that appeared on the computer screen. The arrow indicates that the screen on the right followed the screen on the left. The experimenter-designated correct choice is indicated by a circle. Experimental stimuli are labeled using Alphanumerics and the contextual cue is denoted by the English word “OPPOSITE” for the sake of clarity –subjects were not exposed to these labels.

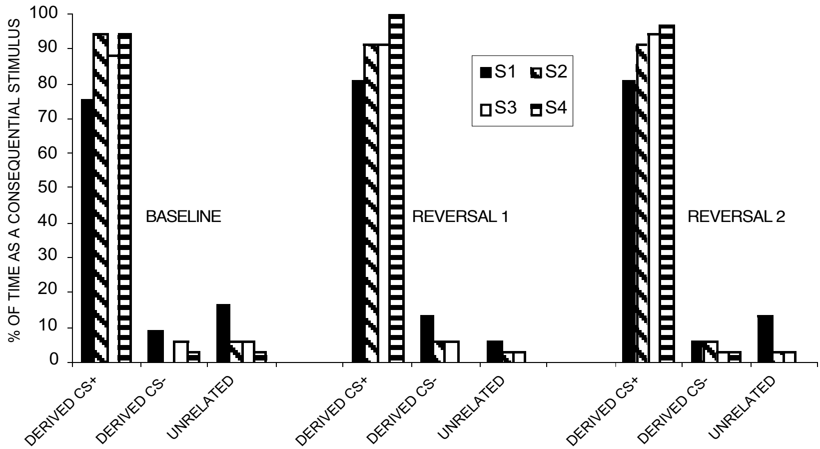

Figure 3. Data for Subjects 1-4 in Phase 4, the test for transformation of consequential

with the conditioned CS- (i.e., B2). If a subject failed to demonstrate the predicted transformation of consequential functions, then he or she was re-exposed to Phases 1-4.

Figure 2 displays diagrammatic representations and brief descriptions of the typical experimental tasks that were presented during the four phases.

Reversal 1. During this phase, subjects were re-exposed to Phases 2-4, but, during the arbitrary relational training phase the contextual cues in two of the relational training trials were reversed; SAME/A1-B1 became OPPOSITE/A1-B1, and OPPOSITE/A1-B2 became SAME/A1-B2).

Reversal 2. In Reversal 2 the contextual cues were reversed in the following way; SAME/A1-C1 became OPPOSITE/A1-C1, and OPPOSITE/A1-C2 became SAME/A1-C2. Hence, in Reversal 2, the derived combinatorially entailed relations that were predicted to emerge in the transformation of consequential functions test were identical to those that emerged in the first transformation of consequential functions test (see Figure 1 for a diagrammatic representation of the procedure).

Across the first exposure, and across Reversals 1 and 2, if subjects did not produce the predicted performance during Phases 2, 3, or 4 they were re-exposed to that particular phase again.

Results and Discussion

Four subjects began Experiment 1. All subjects reached criterion in the relational test, requiring between one and seven exposures to Phase 3. Successful completion of the transformation of consequential functions test was defined as consistently choosing the stimulus that produced the member of the relational network that was in a frame of opposition with the putative CS-. Figure 3 displays the performances in Phase 4 for Subjects 8-11, and also displays the relation obtained between B2, the directly-established CS-, and each stimulus in the relational network.

In Experiment 1, all subjects reliably chose the stimulus that was in a frame of opposition with the CS- in all transformation of consequential functions probes. Thus, the results of the experiment presented here indicate that a punishing function attached to one stimulus appears to transform the functions of a second stimulus that is combinatorially entailed through a relation of Opposite, such that the second stimulus acquires a reinforcing function. The current study thus extends that of Hayes et al. (1991) by examining transformation of consequential functions among non-equivalent stimuli and demonstrating within-subject reversals in the transformation of consequential functions.

Experiment 2: Formative augmenting in accordance with the relations of more-than and less-than

Procedure

The procedure in Experiment 2 consisted of: Phase 1, nonarbitrary relational training and testing; Phase 2, arbitrary relational training and testing; Phase 3, training stimulus-consequence relations; Phase 4, establishing consequential functions; and Phase 5, a simultaneous discrimination phase that tested for the transformation of consequential

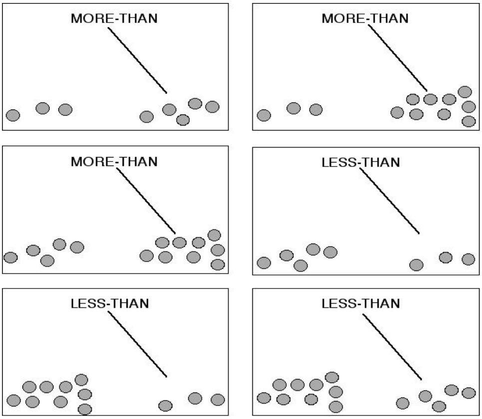

Figure 4. All possible trial types using a particular stimulus set. The relational words "MORE-THAN" and "LESS-THAN" are used for the sake of clarity: subjects were not exposed to these labels.

functions. The following convention is used for describing both the nonarbitrary and arbitrary relational training and testing probes: the contextual cue is given first in capitals, followed by the comparisons in brackets, with the reinforced comparison given first.

Phase 1: Nonarbitrary relational training and testing. The aim of this phase was to establish functions of More-than and Less-than for the contextual cues (arbitrary shapes) that were to be used in the arbitrary relational training and testing phase. There were 16 stimulus sets employed in this phase, each composed of images of different quantities of a particular object, termed "Few" for the smallest amount, then "Intermediate" (note: not necessarily the midpoint of the least and greatest amounts), and "Many" for the greatest amount. For example, one stimulus set was composed of images of three, five, and nine dots. Figure 4 displays all possible trial types using a particular stimulus set. The nonarbitrary stimulus sets were as follows (the quantities of the particular object that composed each image are in parentheses): Apples (1, 4, 7), Basketballs (1, 2, 8), Beakers (1, 3, 6), Toy Blocks (1, 3, 7), Boats (1, 2, 3), Cherries (4, 6, 18), Dots (3, 5, 9), Hats (1, 3, 7), Ladybirds (2, 4, 8), Leaves (1, 3, 5), Pencils (1, 2, 3), Pigs (3, 12, 18), Pumpkins (1, 2, 3), Tractors (1, 2, 3), Traffic Lights (1, 3, 4), and Turtles (2, 3, 4).

On all trials, the two comparison stimuli appeared simultaneously in a row at the bottom of the screen, and then 1 s later the contextual cue appeared in the middle of the screen. The contextual cue and comparison stimuli remained on the screen together until the subject selected one of the comparison stimuli (by clicking over it with the mouse). The position of the comparison stimuli (left or right) was counterbalanced across trials. During the nonarbitrary relational training phase, feedback was presented in the center of the screen for 1.5 s, and consisted of the words "Correct" or "Wrong". All trials were followed by an intertrial interval of 2.5 s during both nonarbitrary relational training and testing.

In the presence of the MORE-THAN contextual cue, selecting the image that portrayed the greater quantity of a particular object was reinforced. For example, if the comparison stimuli were images of three dots and of five dots, then choosing the image of five dots was reinforced. In the presence of the LESS-THAN contextual cue, selecting the image that portrayed the lesser quantity of a particular object was reinforced. Each subject was required to choose the correct comparison stimulus across 10 consecutive trials in order to reach the mastery criterion for this phase.

On reaching the criterion for nonarbitrary relational training, subjects were exposed to a nonarbitrary relational test phase. Feedback was terminated without warning, and the eight novel stimulus sets were employed. If a subject failed to produce less than 16 correct responses, he or she was reexposed to Phase 1 from the beginning. Having passed this test phase, subjects proceeded immediately to Phase 2.

Phase 2: Arbitrary relational training and testing . The aim of this phase was to train responding in accordance with a linear ranking relational network, composed of seven arbitrary stimuli. The format of the trials was the same as that employed

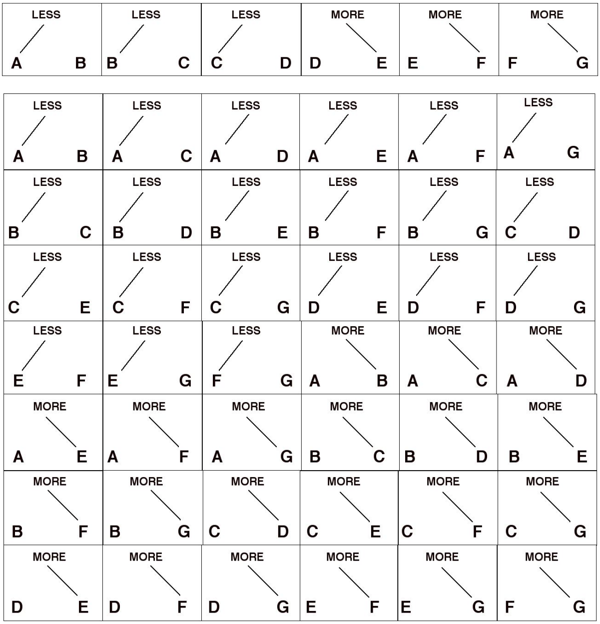

Figure 5. Schematic representations of the arbitrary relational training (top panel) and testing (lower panel) trial types. The relational words "MORE" and "LESS" are used for the sake of clarity: subjects were not exposed to these labels.

during the nonarbitrary relational training. The trial types were as follows; LESS-THAN[AB], LESS-THAN[BC], LESS-THAN[CD], MORE-THAN[DE], MORE-THAN[FE], MORE-THAN[GF] (see Figure 5, top panel). Relational training trials were presented quasi-randomly in blocks of 18 trials, with each trial type presented three times within each block. Subjects were required to respond correctly across 16 of the 18 trials, with no more than one error on any one trial type, in order to reach the mastery criterion for the relational training.

Upon reaching this criterion, subjects were exposed to the relational test phase. Feedback was terminated without warning in this test phase. Subjects were presented with 72 conditional discriminations (see Figure 5, lower panel), testing all possible derived relations twice. Subjects were required to respond correctly across all trials in this phase in order to reach the mastery criterion.

Phase 3: Training stimulus-consequence relations. During this phase, subjects were presented on each trial with one of eight circles, each with a different arbitrary pattern, and were required to click on the circle with the mouse. This response was consequated with the presentation of a particular member of the relational network or a novel stimulus (X1) that was to be established as a CS- in the next phase. In effect, each circle was consistently paired with a specific consequential stimulus. Following each block of eight trials, the phrases “Do you need more practice?” and “Click ‘Y’ for Yes or ‘N’ for No” appeared in the middle of the screen. If subjects pressed the “Y” key on the computer keyboard they were presented with another block of eight trials; if subjects pressed the “N” key they were exposed to Phase 4.

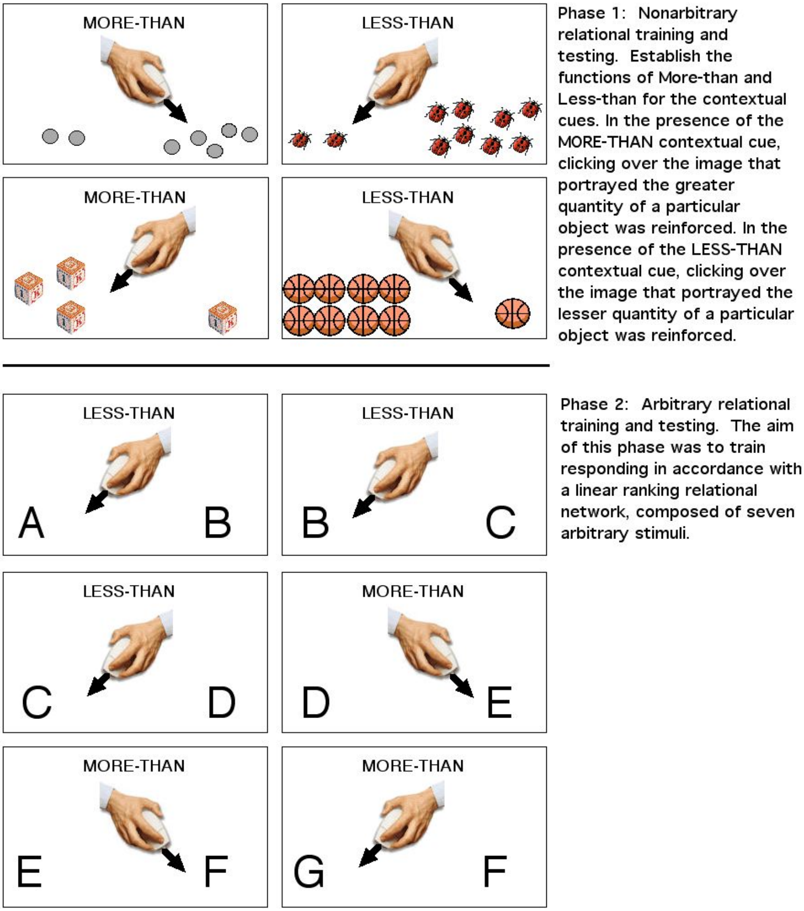

Figure 6. Diagrammatic representations and brief descriptions of the typical experimental tasks that were presented during the four phases. The figures on the left are representative of the tasks that appeared on the computer screen. An arrow indicates that the screen on the right followed the screen on the left. Experimental stimuli are labeled using alphabetical characters and the contextual cues are denoted by the words “MORE-THAN” and “LESS-THAN” for the sake of clarity – subjects were not exposed to these labels.

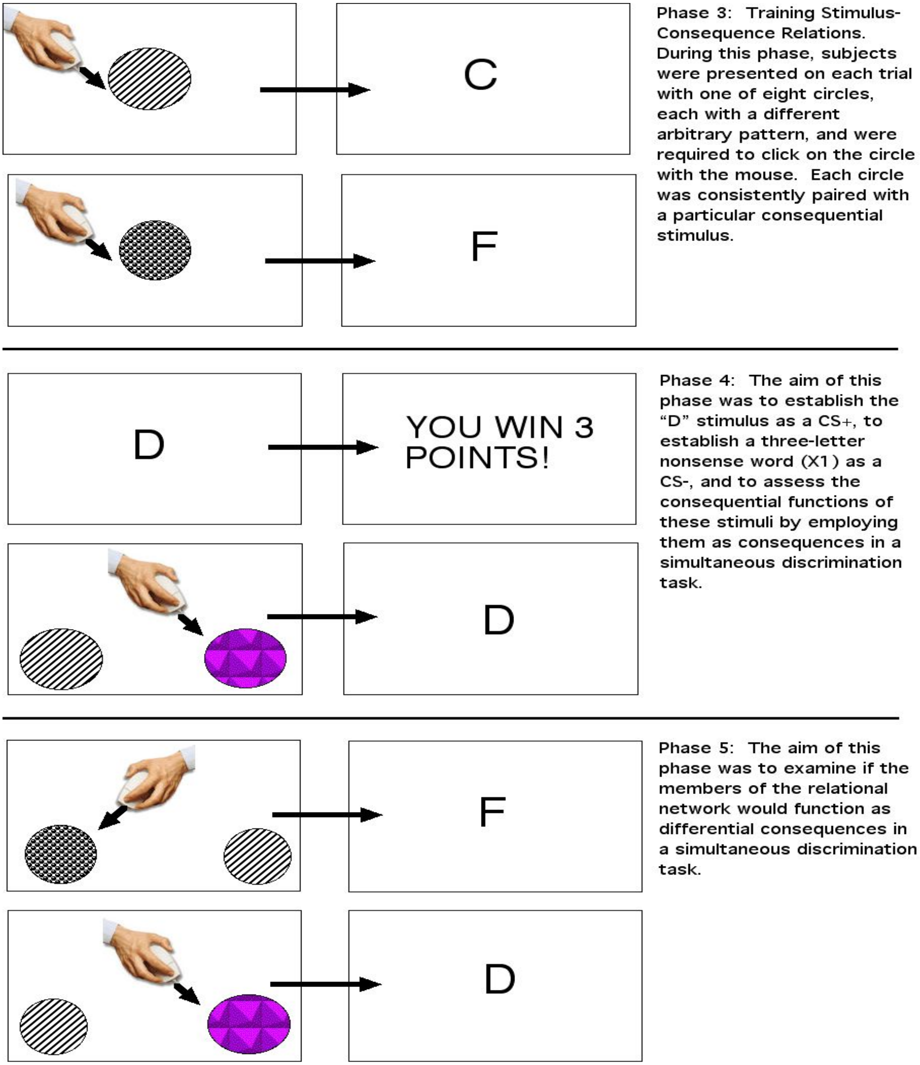

Figure 6 (Cont.)

Phase 4: Establishing consequential functions. The aim of this phase was to establish the “D” stimulus as a CS+, to establish a three-letter nonsense word (X1) as a CS-, and to assess the consequential functions of these stimuli by employing them as consequences in a simultaneous discrimination task. This phase was composed of two blocks: one block consisting of 10 trials of stimulus-pairing, the other consisting of 8 blocks: one block consisting of 10 trials of stimulus-pairing, the other consisting of 8 trials of simultaneous discriminations. In order to reach criterion for this phase, subjects were required to choose the circle that produced the D stimulus across at least the final eight trials of the simultaneous discrimination task before proceeding to Phase 5; otherwise, the subject was exposed to another 10 stimulus-pairings and 8 simultaneous discrimination probes.

Phase 5: Test for transformation of consequential functions. The aim of this phase was to determine if the members of the relational network would function as differential consequences in a simultaneous discrimination task. The simultaneous discrimination probe trials were similar to those presented in Phase 4, except that now the members of the relational network were employed as the corresponding consequences. Subjects were presented with 42 simultaneous discriminations. The instructions for Subjects 6-9 were as follows:

> *"During this part of the experiment you will be presented with two circles and you must choose the circle that you think will get you the most points"*.

This was the final phase of the experiment, and when it was concluded each subject was thanked and fully debriefed. An overview of the procedure is displayed diagrammatically in Figure 6.

Alterations in the baseline contingencies

Following the test for transformation of consequential functions (Phase 5) the

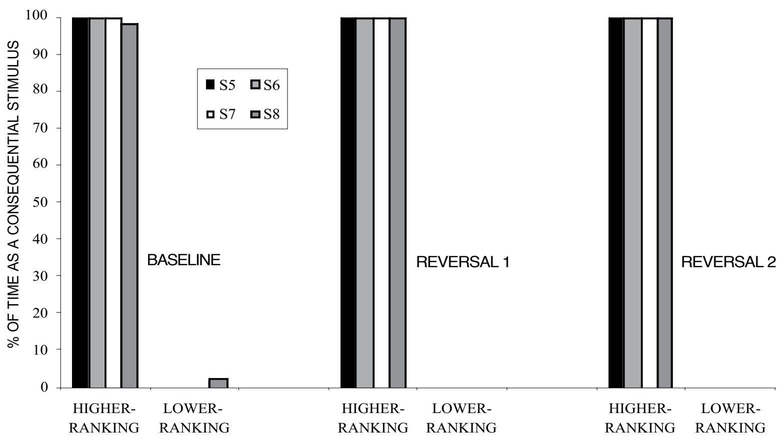

Figure 7. Data for Subjects 5-8 in Phase 5, the test for transformation of consequential functions, of Experiment 2, across the Baseline, Reversal 1, and Reversal 2 conditions.

relations among the stimuli in the relational network were manipulated using an ABA reversal design. Specifically, following the first test for the transformation of consequential functions, subjects were reexposed to Phase 1, which remained identical throughout the experiment. However, in Phase 2, the arbitrary relational training trials were altered. In the case of Subject 6, all the relations among the stimuli in the relational network were simply reversed (i.e., the relational network changed from A<B<C<D<E<F<G to G<F<E<D<C<B<A). For Subjects 7-9 the relational network was entirely re-ordered. That is, every stimulus in the relational network had a different position in the linear ranking string following Phase 2. Specifically, for Subject 7 the relational network changed to F<C<G<E<B<D<A; for Subject 8 the relational network changed to D<G<A<F<D<B<C; and for Subject 9 the relational network changed to B<F<D<A<G<E<C. Finally, all subjects were reexposed to the entire procedure again, during which the original baseline relations were reestablished.

Results and Discussion

All subjects in Experiment 2 passed Phase 1 on their first attempt, passed Phase 2 within three exposures, and reached the criterion in Phase 4 within a maximum of two exposures. In Phase 5, all subjects chose the stimulus that produced the higher-ranking member of the relational network across at least 40 of 42 probe trials. Following the alteration of the baseline contingencies in Phase 2 (arbitrary relational training and testing), all subjects successfully completed the test for transformation of consequential functions, choosing the stimulus that produced the higher-ranking member of the relational network across all 42 probe trials. On reexposure to the baseline contingencies in Alteration 2, all subjects produced the predicted performance, choosing the stimulus that produced the higher-ranking member of the relational network. Figure 7 displays the results for Subjects 6-9.

In this experiment, all four subjects completed all tests for the transformation of consequential functions in accordance with the relational frames of More-than and Less-than. Furthermore, the data reported here demonstrate that performances in the transformation of consequential functions test were sensitive to alterations in the previously trained relational performances.

Discussion/Conclusion

The results of Experiments 1 and 2 indicate that a consequential function given to one member of a relational network can be transformed in accordance with the relations within that network. Experiment 1 demonstrated that a reinforcing function attached to one stimulus appears to transform the functions of related stimuli in accordance with the relations of Same and Opposite. The data from Experiment 2 suggest that reinforcing functions can be transformed in accordance with the relations of More-than and Less-than. Furthermore, both these studies indicate that the relational performances are sensitive to the baseline contingencies: thus the reinforcing and punishing properties of stimuli can be correspondingly altered. The results of the experiments presented here are important because they demonstrate that formative augmentals influence behavior, even though some consequences were never actually contacted.

Consistent with other studies that examined multiple stimulus relations (e.g., Dymond & Barnes, 1995; Steele & Hayes, 1991), the performances described above do not seem to be easily interpretable in terms of equivalence classes. The terms used to describe the properties of an equivalence relation – reflexivity, symmetry, and transitivity – do not seem to be applicable to the kinds of relational performances demonstrated in the current experiments. For example, the properties of More-than and Less-than responding seem to have more in common with temporal or order relations (Green & Stromer, 1993), in that the relations are irreflexive, asymmetrical, transitive, and connected. First, the relation that the A stimulus has with itself is not reflexive: it cannot be More-than or Less-than itself. Second, if A is More-than B, it does not follow that B is also More-than A: the relation is not symmetrical. The relations are transitive, if B is More-than A and C More-than B then C is More-than A. The relations are also connected, because all stimuli that participate in a specific More-than or Less-than relation are related to each other. The current data, therefore, support and extent not only studies within the literature on relational frame theory, but also those studies that have attempted to extend Sidman's set theory analysis of equivalence classes (e.g., Sidman, 1997) to non-equivalence relations.

Skinner (1953) suggested that it is "characteristic of human behavior that primary reinforcers may be effective after a long delay" (p. 77). Expanding on this observation, Barnes-Holmes, Hayes & Gregg (2001) and Hayes & Wilson (1993) noted that human behavior can be regulated by verbally constructed consequences, even though the primary reinforcers may never be contacted. For example, a teenager may faithfully abide by a particular set of religious rules in order to avoid "going to hell". If the teenager is told: "premarital sex is a sin", this statement may function as a formative augmental – such that the functions of sexual activity (an unconditioned reinforcer) are transformed, and abstinence is a now derived reinforcer. Behaviors under this type of control are similar to those described in Experiment 1, where consequences functioned as either reinforcers or as punishers, depending on their derived relation to other stimuli. Furthermore, Experiment 1 involved establishing a single punishing function for one member of the network, and based on the derived relations of Same and Opposite, other members acquired reinforcing functions, although no such function had actually been established for *any* member of the network. These data replicate and extend previous research by indicating that a specific behavioral function can emerge within a relational network without that function being explicitly trained to *any* member of the network (cf. Roche & Barnes, 1997).

Experiment 2 was an empirical demonstration of formative augmenting in accordance with comparative frames: in the natural environment this behavior might be as follows. A teenager who is about to visit the USA for the first time would likely be told that coins range in value from a penny, to a nickel, to a dime, to a quarter, and finally, to a one dollar coin. The teenager may derive a number of relations among these coins (e.g., a quarter is worth more than a nickel, and a penny is worth less than a dollar etc.). Furthermore, the relative reinforcing functions of any pair of these coins would likely be affected in accordance the trained and derived More-than and Less-than relations. For example, given a choice between a penny and a nickel, the teenager would choose the latter, but given the choice between a nickel and dollar, the teenager would avoid the nickel and choose the dollar.

The models of formative augmenting described in the current paper may bolster the relational frame account of human language and cognition by providing empirical support for descriptions of complex behaviors as they occur in the natural environment. It should be noted, however, that some important issues remain to be addressed. For example, the current study employed verbally sophisticated adults, each of whom had unknown preexperimental histories with the relations of Same, Opposite, More-than and Less-than. Presumably, these preexperimental histories played an important role in facilitating the performances observed in the current study. Nevertheless, achieving prediction and control though multiple reversals in the baseline contingencies, over formative augmenting in accordance with multiple stimulus relations, is an important step towards a more complete analysis of the acquisition and maintenance of consequential functions in human adults.

References

Barnes-Holmes, D., Hayes, S.C., Dymond, S., & O'Hora, D. (2001). Multiple stimulus relations and the transformation of stimulus functions. In S.C. Hayes, D. Barnes-Holmes, B. Roche (Eds.), *Relational frame theory: A post-Skinnerian account of human language and cognition*. Reno, NV: Context Press.

Barnes-Holmes, D., Hayes, S.C., & Gregg, J. (2001). Religion, Spirituality, and Transcendence. In S. C. Hayes, D. Barnes-Holmes, B. Roche (Eds.), *Relational frame theory: A post-Skinnerian account of human language and cognition*. Reno, NV: Context Press.

Barnes-Holmes, D., O'Hora, D., Roche, B., Hayes, S.C., Bisset, T., & Lyddy, F. (2001). Understanding and verbal regulation. In S.C. Hayes, D. Barnes-Holmes, B. Roche (Eds.), *Relational frame theory: A post-Skinnerian account of human language and cognition*. Reno, NV: Context Press.

Barnes-Holmes, Y., Barnes-Holmes, D., Roche, B., Healy, O., Lyddy, F., Cullinan, V.A., & Hayes, S.C. (2001). Psychological Development. In S.C. Hayes, D. Barnes-Holmes & B. Roche (Eds.), *Relational frame theory: A post-Skinnerian account of human language and cognition*. Reno, NV: Context Press.

Cohen, J.D., MacWhinney, B., Flatt, M., & Provost, J. (1993). Psyscope: a new graphic interactive environment for designing psychology experiments. *Behavioral research methods, instruments and computers, 25*, 257-271.

Dymond, S. & Barnes, D. (1995). A transformation of self-discrimination response functions in accordance with the arbitrarily applicable relations of sameness, more than, and less than. *Journal of the Experimental Analysis of Behavior, 64*, 163-184.

Dymond, S. & Barnes, D. (1996). A transformation of self-discrimination response functions in accordance with the arbitrarily applicable relations of sameness and opposition. The

Psychological Record, 46, 271-300.

Green, G., Stromer, R., & Mackay, H.A. (1993). Relational learning in stimulus sequences. The *Psychological Record, 43*, 599-615.

Hayes, S.C., Kohlenberg, B.S., & Hayes, L. J. (1991). The transfer of specific and general consequential functions through simple and conditional equivalence relations. *Journal of the Experimental Analysis of Behavior, 56*, 119-137.

Hayes, S.C., & Wilson, K.G. (1993). Some applied implications of a contemporary behavior-analytic account of verbal events. *Behavior Analyst, 16*, 283-301.

O'Hora, D., Barnes-Holmes, D., Roche, B., & Smeets, P.M. (2002). Response latencies to multiple derived stimulus relations: Testing two predictions of relational frame theory. *The Psychological Record, 52*, 51-75.

Roche, B. & Barnes, D. (1996). Arbitrarily applicable relational responding and sexual categorization: A critical test of the derived difference relation. *The Psychological Record, 46*, 451-475.

Roche, B. & Barnes, D. (1997). A transformation of respondently conditioned stimulus function in accordance with arbitrarily applicable relations. *Journal of the Experimental Analysis of Behavior, 67*, 275-301.

Roche, B., Barnes-Holmes, D., Smeets, P.M., Barnes-Holmes, Y., & McGready, S. (2000). Contextual control over the derived transformation of discriminative and sexual arousal functions. *The Psychological Record, 50*, 267-291.

Roche, B., Stewart, I., & Barnes-Holmes, D. (1999). Psyscope: an easy-to-use graphical system for designing and controlling equivalence experiments. *The Experimental Analysis of Human Behavior Bulletin, 21*, 37-52.

Sidman, M. (1992). Equivalence: Some basic considerations. In S.C. Hayes & L.J. Hayes (Eds.), *Understanding verbal relations* (pp. 15-27). Reno, NV: Context Press.

Sidman, M. (1997). Equivalence: A theoretical or descriptive model? *Revista Mexicana de Analisis de al Conducta, 23*, 125-145.

Skinner, B. F. (1953). *Science and human behavior*. New York: Macmillan.

Steele, D.L. & Hayes, S.C. (1991). Stimulus equivalence and arbitrary applicable relational responding. *Journal of the Experimental Analysis of Behavior, 56*, 519-555.

Whelan, R. (2002). Derived stimulus relations under contextual control produce association and mediated priming. *Experimental Analysis of Human Behavior Bulletin, 20*, 22-23.

Received November 20, 2003
Final acceptance March 30, 2004