RESEARCH IN PROGRESS

MODELING ANALOGICAL REASONING USING THE RELATIONAL EVALUATION PROCEDURE

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Our current work aims to model analogy using the Relational Evaluation Procedure (REP), a novel experimental protocol allowing the rapid generation of derived relations (e.g., Hayes, Barnes-Holmes & Roche, 2001). Recent behavior analytic work has conceptualized analogy as the derivation of equivalence relations between equivalence and other types of derived relations (e.g., more than/less than) and this conceptualization has been successfully modeled in the laboratory (e.g., Barnes, Hegarty & Smeets, 1997). However, previous empirical demonstrations of this model have been based on matching-to-sample (MTS) procedures, which allow only a limited number of analogies to be demonstrated. Our employment of the REP is intended to circumvent this difficulty, thus enabling the development of a model of analogy that captures the often rapid and relatively easy use of analogy in natural language.

BACKGROUND

Barnes et al. (1997) provided the first behavior analytic model of analogy based on responding in accordance with equivalence relations between equivalence relations. In the authors' own words;

> Consider...the following question…: "apple is to orange as dog is to: (i) sheep, or (ii) book?". If "apple" and "orange" participate in an equivalence relation in the context "fruit," and "dog" and "sheep" participate in an equivalence relation in the context "animals" then we would expect a person to pick "sheep" as the correct answer. In effect, the response would be in accordance with the derived equivalence relation between two already established separate equivalence relations...We take the view that equivalence-equivalence responding is an example of a relational network as defined by relational frame theory…(p. 3)

Barnes et al. (1997) trained subjects, using matching-to-sample procedures, to make the following conditional discriminations: A1->B1, A2->B2, A1->C1, A2->C2, A3->B3, A3->C3, A4->B4, A4->C4. Four equivalence relations then emerged: B1<->C1, B2<->C2, B3<->C3, B4<->C4. Subsequent tests then demonstrated the emergence of equivalence relations between equivalence relations (e.g., B1C1<->B3C3) and of equivalence relations between non-equivalence relations (e.g., B1B2<->C3C4).

Stewart et al. (2001) recently extended this model. They argued that, in addition to the arbitrary relations established by Barnes et al. (1997), analogy often involves the abstraction of common formal properties. In the example given above, for instance, the arbitrary equivalence relation between "apple" and "orange" is based, to some degree, on non-arbitrary similarity between actual apples and oranges (e.g., 'sweetness'). Similarly, the arbitrary equivalence relation between "dog" and "sheep" is based on non-arbitrary similarity between actual dogs and actual sheep (e.g., 'four legged-ness'). Thus, the equivalence-equivalence (analogical) relation between the equivalence relations 'apple-orange' and 'dog-sheep' may be traced back to formal relations. Stewart et al. (2001), therefore, attempted to include the role of formal properties in the Barnes et al. (1997) model. Subjects were taught, using matching-to-sample, to choose a particular nonsense syllable in the presence of each of four blue and four red geometric shapes. In a subsequent test, subjects demonstrated equivalence responding based on the abstraction of color by consistently matching nonsense

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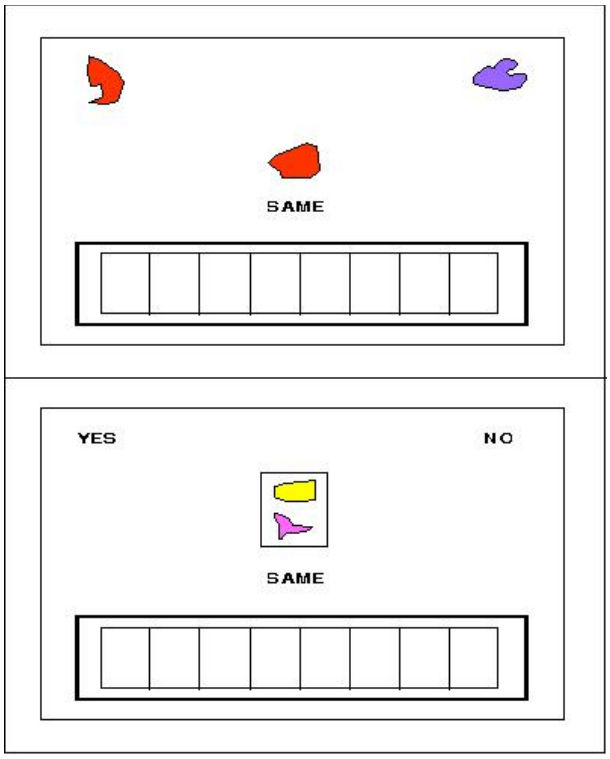

Figure 1

syllables related to same-colored shapes to each other. Subjects then showed equivalence-equivalence responding. Thus, these researchers provided a demonstration of equivalence-equivalence responding based on the abstraction of common formal properties, thereby extending the functional-analytic model of Barnes et al. (1997) to incorporate what they argued was an essential feature of analogical reasoning.

Stewart et al. provided an important extension to the model reported by Barnes et al. However, both these demonstrations were based on matching-to-sample training, which allowed only a limited number of analogies to be shown, and thus these models lacked the generativity characteristic of everyday analogy. In order to demonstrate a more ecologically valid model of analogy, we have adopted the REP, which allows for the rapid generation of derived relations. In what follows, we will describe the REP-based procedures we are currently using to model analogy.

MODELING ANALOGY USING THE RELATIONAL EVALUATION PROCEDURE

The Relational Evaluation Procedure is a protocol that allows subjects to evaluate, or report on, the networks of derived stimulus relations with which they are presented. In the typical approach, subjects may confirm or deny the applicability of particular stimulus relations to other sets of stimulus relations. Our REP-based model of analogy involves seven stages of training and testing.

Stage 1: Establishing SAME and DIFFERENT functions. Subjects are trained, using a delayed, 2-comparison, matching-to-sample format (see Figure 1; upper panel), to choose a comparison the same color as the sample in the presence of an arbitrary shape designated SAME. Similarly, choosing a comparison different in color from the sample, in the presence of an arbitrary shape designated DIFFERENT, is also trained. Thus, the functions of SAME and DIFFERENT are established for these shapes. In Stages 1, 2 and 3, once sufficient training has been received, the subject is tested on a novel set of tasks.

Stage 2: Establishing YES and NO functions. Subjects are presented with two same- or differently-colored shapes, a contextual cue (i.e., SAME or DIFFERENT), and two novel, arbitrary comparison shapes (designated YES and NO; see Figure 1, lower panel). Subjects are trained to choose the YES comparison when the contextual

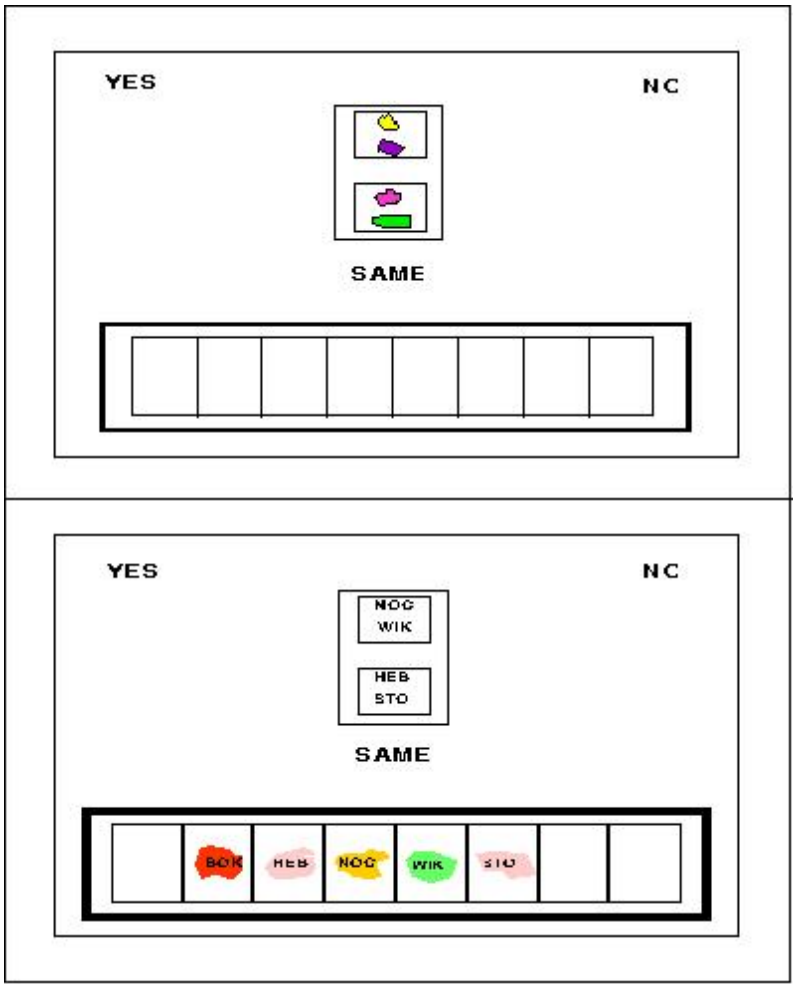

Figure 2

cue correctly corresponds to the relationship between the colored shapes (i.e., 'same color' or 'different color'). If it does not correspond then they should choose the NO comparison. For example, if a green shape appears with a yellow shape, and the DIFFERENT cue is also presented, then choosing YES is trained. YES and NO functions are thereby established in two arbitrary stimuli.

Stage 3: Establishing responding to relations between relations. This stage is similar to YES / NO Pretraining, involving same- or differently-colored shapes, a contextual cue, and the YES / NO comparisons. However, instead of two colored shapes in the box in the center of the screen, there are now two boxes, each containing two colored shapes (Figure 2, upper panel). Subjects are trained to respond in accordance with the relation obtaining between these colored-shape relations. For example, if green and orange shapes (different) appear in one box, and two pink shapes (same) appear in the other box, then the two non-arbitrary relations presented are different. Hence, if the contextual cue is DIFFERENT, then choosing YES is trained, whereas if it is SAME, then choosing NO is trained.

Stage 4: Introducing nonsense syllables. Stage 4 also involves responding in accordance with relations between relations. There is a contextual cue above the chambered box, and above that there is a box in the center of the screen that contains two smaller boxes, each of which contains two stimuli. However, instead of colored shapes, the stimuli in the boxes are nonsense syllables (Figure 2, lower panel). The eight-chambered box at the bottom of the screen now also contains nonsense syllables in black letters superimposed upon various novel colored shapes. Subjects are

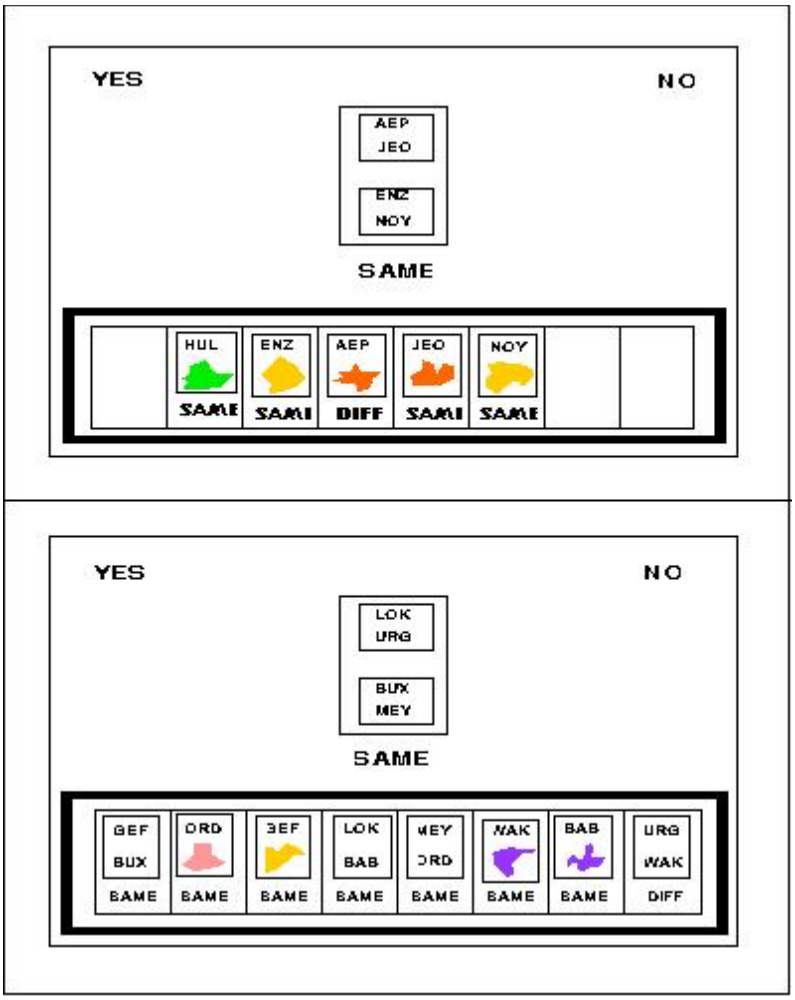

Figure 3

required, based on prior instructions, to look at this lower chamber before looking at the middle and upper portions of the screen. Based on spatial contiguity, the nonsense syllables in the lower chamber might be expected to acquire the color functions of the shapes upon which they are superimposed. In addition, because four of the nonsense syllables appearing in the bottom chamber appear also in the box in the center of the screen, subjects should respond to these four nonsense syllables as "standing for" particular colors, and thus respond in accordance with relations between relations as in Stage 3.

Stage 5: Relating relations based on mutual entailment. This stage is similar to the previous stage, except that the nonsense syllables in each of the chambers are no longer superimposed upon the colored shapes but appear above them (see Figure 3; upper panel). In addition, the nonsense syllable and colored shape in each chamber appear in a box above a particular contextual cue, either SAME or DIFFERENT. Thus, in this stage, subjects are required to observe the two relations (colored shape and nonsense syllable) and the contextual cue in each chamber of the eight chambered box before looking at the images appearing above. Based on an experimental history of responding in the presence of the particular contextual cues, the functions of the nonsense syllables should transform in certain predictable ways for the subjects. More specifically, in the presence of SAME, a nonsense syllable should acquire the same color function as the shape over which it appears, while in the presence of DIFFERENT, a nonsense syllable should acquire a function of 'different color from the shape over which it appears'. Subjects should then respond in accordance with relations

between relations in the same manner as in previous stages. The phrase 'mutual entailment' in the title of this sub-section refers to the fact that the relations between the nonsense syllables and the colored shapes, upon which analogical responding is based, are mutually entailed relations (i.e., the nonsense syllables appearing in the upper boxes are directly related to the colored shapes).

Stage 6: Relating relations based on combinatorial entailment. In this stage, the relations between the colored shapes and the nonsense syllables are relations of combinatorial entailment (i.e., the nonsense syllables appearing in the upper boxes are indirectly related to the colored shapes; see Figure 3, lower panel). For example, in one chamber, a purple shape and the nonsense syllable "CUG" may appear together over the "SAME" contextual cue, while in another box, two nonsense syllables, "CUG" and "ZID" may appear together over the "SAME" contextual cue. Thus, subjects may respond to ZID as purple because it is in a combinatorially entailed "SAME" relation with the purple shape. The other nonsense syllables might acquire certain color functions based on a similar process. After that, subjects should respond in accordance with relations between relations in the same manner as in previous stages.

Stage 7: Test for analogy involving novel colors and shapes. This stage is identical to the previous stage, except that it involves completely novel colors and shapes. Hence, this stage should demonstrate numerous, completely novel examples of analogical responding. It is at this point that the REP presents a real advantage over the matching to sample procedure in that generating even one novel analogy using the MTS would require training and testing a whole new set of equivalence relations. In contrast, Stage 7 of the REP allows the experimenter to demonstrate a stream of novel analogies for the subject to solve, some of the advantages of which are mentioned below.

CONCLUSION

Four undergraduate students already exposed to this procedure have produced the predicted performances. Most importantly, in Stage 7, subjects related combinatorially entailed relations based on the abstraction of common physical properties across 24 novel trial-types. In effect, all four subjects demonstrated 24 completely novel analogical responses, and thus, in principle, an infinite number of such responses could be generated using this procedure. This level of complex and genuinely novel relational responding seems to model everyday analogy more closely than the earlier matching-to-sample based procedures. Matching-to-sample allows the training up in a number of hours of a particular analogical relational network. However, in the same period of time, by using the REP protocol, it is possible to train subjects to respond rapidly in accordance with a potentially infinite number of completely novel networks. Thus, this procedure should make the study of relatively complex patterns of analogical and other types of relational responding more efficient. Future REP-based models of analogy, for example, may involve derived relations such as OPPOSITION, COMPARISON, BEFORE / AFTER etc. In addition, stimuli other than simple colored shapes might be incorporated into the analogical network, thus providing more complex and subtle examples of analogy. Furthermore, the effects of other variables (e.g., distractor tasks, the presence of other individuals) on an ongoing stream of analogical responding could be assessed using the REP. Finally, other correlates of analogical responding (e.g., ERPS, fMRI) could also be assessed across multiple analogies in a way that would be extremely difficult if not impossible using traditional MTS procedures.

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