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Conditional discriminations, symmetry, and semantic priming☆

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ABSTRACT

Psychologists interested in the study of symbolic behavior have found that people are faster at reporting that two words are related to one another than they are in reporting that two words are not related – an effect called semantic priming. This phenomenon has largely been documented in the context of natural languages using real words as stimuli. The current study asked whether laboratory-generated stimulus–stimulus relations established between arbitrary geometrical shapes would also show the semantic priming effect. Participants learned six conditional relations using a one-to-many training structure (A1-B1, A1-C1, A1-D1, A2-B2, A2-C2, A2-D2) and demonstrated, via accurate performance on tests of derived symmetry, that the trained stimulus functions had become reversible. In a lexical decision task, subjects also demonstrated a priming effect as they displayed faster reaction times to target stimuli when the prime and target came from the same trained or derived conditional relations, compared to the condition in which the prime and target came from different trained or derived conditional relations. These data suggest that laboratory-generated equivalence relations may serve as useful analogues of symbolic behavior. However, the fact that conditional relations training and symmetry alone were sufficient to produce the effect suggests that semantic priming like effects may be the byproduct of simpler stimulus–stimulus relations.

1. Introduction

Stimulus equivalence refers to the observation that, after having learned a few overlapping conditional relations among stimuli, human subjects will demonstrate a number of other conditional relations among those stimuli without direct training or reinforcement (Sidman et al., 1989; Sidman and Tailby, 1982). For example, having learned to match the stimulus A1 to stimulus B1 (and not B2 or B3) and having learned to match stimulus B1 to stimulus C1 (and not C2 or C3), human participants will readily match B1 to A1, C1 to B1, A1 to C1, and C1 to A1 – without training or reinforcement.

Sets of stimuli for which the above description holds true are called stimulus equivalence classes because they satisfy the requirements of equivalence relations as described in mathematical set theory which states that a relation of equivalence obtains among members of a set if it can be shown that the elements are related via reflexivity, symmetry, and transitivity (cf. Sidman, 1994). Laboratory generated equivalence classes have a number of interesting characteristics that have led researchers to suggest that they may serve as effective analogues of linguistic and other complex human performances. Notice, first, that replacing the non-representative forms that are typically used in equivalence studies with everyday stimuli (the spoken word 'cat', a picture of a cat, the written word [cat], etc.) immediately transforms the conditional relations that define equivalence classes into linguistically relevant performances. For example, trials in which pictures serve as sample stimuli and the written or spoken word serve as comparison stimuli are good analogues of picture comprehension and trials in which the written word serves as the sample stimulus and the picture and spoken word serve as comparisons are good analogues of word comprehension and reading, respectively.

Furthermore, research has shown that stimulus functions established for one member of an equivalence class will extend to other members of the equivalence class without any training or contingencies supporting such extension (e.g.; Catania et al., 1989; Dougher et al., 1994). For example, Dougher et al. first directly trained two overlapping conditional discriminations and documented the existence of 2, four-member equivalence classes. The experimenters then established a conditioned-startle reflex with

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one element (B1) of the existing equivalence class and tested for the extension of that stimulus function to other class members (C1 and D1). They found that the conditioned-stimulus functions of B1 readily transferred to other members (C1 and D1) of the equivalence classes. This observed extension of function also mimics an important feature of natural languages, namely, the ability of a word (or a collection of words) to serve as a symbol for object or events (generically, referents) in the world. Laboratory-generated equivalence classes, then, may have properties that mimic certain aspects of linguistic functioning and may, therefore, serve as useful analogs for the laboratory study of such complex behavior.

These definitional and extra-definitional properties of laboratory-generated equivalence classes have led behavioral researchers to suggest that laboratory-generated stimulus equivalence relations and naturally developing and expanding semantic networks may be related (Barnes and Hampson, 1993; Cullinan et al., 1994; Fields, 1987; Hayes and Hayes, 1992; Reese, 1991; Sidman, 1986). It is important, however, to ascertain the extent to which laboratory-generated equivalence relations have the properties of more naturally occurring linguistic phenomena. One such phenomenon, of great interest to linguists and cognitive psychologists, is the semantic-priming effect.

1.1. Semantic priming

In general, priming refers to a behavioral change in responding to a stimulus as a function of previous exposure to the same or related stimuli (Voss et al., 2010; Voss et al., 2010Voss et al., 2010; Schacter, 1987; Richardson-Klavehn and Bjork, 1988). "Semantic priming" refers to the observation of priming effects with words as stimuli in human participants. For instance, participants are faster in reporting that two words are related to each other than they are to report that two words are not related to each other (e.g., Meyer and Schvaneveldt, 1971). The task typically used to assess semantic priming is called the Lexical Decision Task (LDT). A typical trial begins with the presentation of a *prime* stimulus (usually a spoken or printed word) followed quickly by a *target* stimulus (also usually a spoken or printed word). The participant is then required to report whether the words are related or not by pressing one of two buttons to indicate a 'yes' or 'no' response. Two main measures fall out of this task. One is a measure of the participant's choices following the presentation of the *target* stimulus (e.g., whether the participant says "yes" or "no"). The second is a measure of the time the participant takes to make either response.

A common finding in these procedures is that participant's reaction times are systematically faster when they are accurately reporting "Yes" than when they are accurately reporting "No". For example, if asked whether two words go together (say 'YES') or not (say 'NO'), participants are faster to say "Yes" (or select Yes) when the words are "*animal*" and "*tiger*" than they are to say "No" (or select No) when the words are "*animal*" and "*coffee*". The faster reaction times for related words are said to be the result of more efficient retrieval dynamics resulting from generalized activation of the semantic network by the presentation of the prime stimulus (e.g., Meyer and Schvaneveldt, 1971).

If equivalence relations are to serve as viable analogues or models of naturally occurring semantic networks (Hayes and Hayes, 1992; Sidman, 1986), it is important to ascertain whether stimuli within equivalence classes are effective as primes and targets relative to stimuli not related via equivalence. The results of two studies (Hayes and Bisset, 1998; Barnes-Holmes et al., 2005) suggest that equivalence relations among otherwise unrelated stimuli are sufficient to produce the semantic priming effect. For example, Barnes-Holmes et al. trained the prerequisites for and documented the existence of two 4-member equivalence classes using nonsense words. After training and testing was complete, participants completed a LDT utilizing the stimuli comprising the equivalence classes as well as novel stimuli. Across the three experiments the researchers found priming effects for stimuli in equivalence classes. An important contribution of the Barnes-Holmes et al. study was their use of procedures that were typical of the conventional research on semantic priming which makes the task of comparing the effects of other variables of interest easier.

The current study sought to expand the conditions under which the relation between equivalence classes and semantic priming are investigated. Toward that end, the first change, relative to earlier studies, was the use of non-representative forms as stimuli. The use of nonsense words as stimuli leaves open the possibility that factors like stimulus generalization (from real words) may contribute to the observed effects in unknown ways. By contrast, a priming effect observed with nonverbal and non-representational stimuli would permit a stronger test of equivalence relations as being sufficient for the priming effect. Voss et al. (2010) have partially demonstrated a semantic priming effect with geometrical shapes, but only with stimuli rated as 'highly meaningful' by participants, and without intraexperimentally establishing the semantic relations of interest.

Along similar lines, this study attempted to more clearly isolate the role of conditional discrimination training and testing on semantic priming by conducting the LDT both before and after conditional discrimination training and prior to testing for emergent symmetry. Presenting the LDT prior to any exposure to the stimuli and training conditions allowed us to see if there was any naturally-occurring priming in the stimulus relations of interest. It was assumed that these data would allow for a cleaner interpretation of the role of the programmed training and testing contingencies on any observed priming.

A third change in the training conditions was also designed to reduce unknown sources of variability in the priming effects of interest in the study. Several studies have shown that linear training structures can potentially introduce associative distance between members of an equivalence class (Fields et al., 1984, 1995; cf. Imam, 2001, 2006) and the effects of associative distances may involve reaction times in addition to the accuracy of the response (Bentall et al., 1998; Spencer and Chase, 1996; cf. Imam, 2006). In the current study we avoided this potential confound by using a one-to-many training structure and a many-to-one testing structure in which only symmetry (associative distance = 0) was assayed.

2. Methods

2.1. Participants

Six young adults (4 women, 2 men) were recruited from the University of North Texas to participate. The participants were recruited via flyers posted around campus and were selected on the basis of their availability and naïveté with respect to the terms and concepts of the experimental analysis of behavior. Participants were instructed to "do as well as they could". All data collection for a participant occurred in a single meeting and each participant was given $10 for their involvement, regardless of their performance. Each experimental session lasted approximately 45 min depending on the number of trials required by individual participants to meet our training criterion.

2.2. Setting and apparatus

Sessions were conducted in a small room (2 m by 3 m) equipped with a chair, desk, and a Macintosh^{TM} laptop computer (ibook Model A1005 running a G3/900 MHz processor with 256 MB of RAM). Participants interacted with a custom-written software package (MTS version 11.67, Dube and Hirris, 1991) which han-