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Relational Frame Theory and Stimulus Equivalence: Conceptual and Procedural Issues

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Abstract

The article begins with a brief outline of the phenomenon of stimulus equivalence and its relationship to human verbal behavior. Relational Frame Theory is then outlined as a behavior-analytic account of both stimulus equivalence and human language. The experimental procedures that have typically been used to examine stimulus equivalence are then considered, before focusing on a series of studies that have developed two alternative procedures for analyzing equivalence class formation: the respondent-type training procedure and the precursor to the relational evaluation procedure. Relational Frame Theory is used to interpret the results that have arisen from these two methodologies. The article concludes that the empirical and theoretical analyses of stimulus equivalence and derived relations, more generally, will be enhanced considerably through the development of a wide range of experimental preparations.
Key words: Stimulus equivalence, relational frame theory, respondent-type training procedure, precursor to the relational evaluation procedure, language.

Resumen

Este artículo comienza con una breve delimitación del fenómeno de la equivalencia de estímulos y su relación con la conducta verbal humana. A continuación se delimita la Teoría del Marco Relacional como una explicación analítico-conductual tanto de la equivalencia de estímulos como del lenguaje humano. Los procedimientos experimentales que se han usado típicamente para examinar la equivalencia de estímulos se consideran posteriormente, centrándose sobre una serie de estudios que han desarrollado dos procedimientos alternativos para analizar la formación de clases de equivalencia: el procedimiento de entrenamiento tipo respondiente y el precursor del procedimiento de evaluación relacional. La Teoría del Marco Relacional se emplea para interpretar los resultados logrados desde las dos metodologías. Este artículo concluye que los análisis empíricos y teóricos de la equivalencia de estímulos y la derivación de relaciones facilitará considerablemente el desarrollo de un amplio rango de preparaciones experimentales.
Key words: Equivalencia de estímulos, Teoría del Marco Relacional, procedimiento de entrenamiento tipo respondiente, precursor del procedimiento de evaluación relacional, lenguage.

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Psychologists have long been fascinated by novel, emergent, or derived abilities that cannot be traced to a history of direct training or learning. The study of such effects would appear to traverse a wide range of topics in psychology, including the study of generative grammar (e.g., Chomsky, 1957), problem solving (e.g., Newall & Simon, 1972), deductive and analogical reasoning (e.g., Johnson-Laird & Byrne, 1990; Keane, 1988), intelligence (Sternberg, 1985), cognitive development (Piaget, 1967), and many others. In behavioral psychology, there has been a recent resurgence of interest in the study of novel or emergent phenomena, and in particular this research has focused on the phenomenon of stimulus equivalence (Sidman, 1994) and its related effects, known as relational frames (Hayes, Barnes-Holmes, & Roche, 2001).

The current article will begin with a short description of the phenomenon of stimulus equivalence. The main behavior-analytic reasons for studying this effect, including the close relationship between equivalence and human language, are then considered. Relational Frame Theory (RFT) is subsequently outlined as a behavioral account of both stimulus equivalence and human language more generally. We will then consider the experimental procedures that have typically been used to study stimulus equivalence, before focusing on a series of studies, conducted in Ireland and Holland, that have developed two alternative procedures for analyzing equivalence class formation. In reviewing this work, we hope to show that the creation and development of novel experimental preparations can help shed important light upon the controlling variables involved in equivalence class formation, derived relations, and human language and cognition more generally.

Stimulus equivalence and relational frame theory: Conceptual issues

The basic concept of stimulus equivalence has a history dating back to the ancient Greeks (e.g., Aristotle in De Memoria et Reminiscentia, 451b; 1941, p. 610). More recently, in modern psychology, it has emerged as a topic for investigation at various times and under different experimental paradigms. For example, stimulus-response (S-R) learning theorists examined a behavioral effect described as equivalence from the 1930's up until the 1960's (e.g., Hull, 1934; Jenkins & Palermo, 1964; Osgood, 1953). These researchers generally used methods such as paired-associate learning in attempts to develop a mediated generalization model of the phenomenon. The decline in interest in mediation paradigms by the 1960's (see Jenkins, 1963) led to a period of stagnation in basic human behavioral research in general, and it was not until the early 1970's that Sidman first began to develop the rigorous experimental methods, and the conceptual underpinnings, of the contemporary examination of stimulus equivalence.

The phenomenon of stimulus equivalence can be described as follows; when a verbally-able human learns a series of related conditional discriminations, the stimuli involved in those discriminations often become related to each other in ways that were not explicitly trained. The simplest form of conditional discrimination involves four stimuli, two of which may be termed "samples," and two "comparisons." In experimental settings, the stimuli used as samples and comparisons are often visual forms, but they may also involve auditory (e.g., Sidman, 1971), olfactory (e.g., Annett & Leslie, 1995), haptic (e.g., Tierney, De Largy, & Bracken, 1995) or gustatory (Hayes, Tilley, & Hayes, 1988) modalities. Conditional discrimination training normally consists of reinforcing the choice of one comparison (call it B1) when presented with one of the samples (call it A1), and reinforcing the choice of the alternative comparison (B2) when presented with the other sample (A2). Subsequent to such training, if a verbally able human is presented with B1 as a sample s/he will generally choose A1 as a comparison, and if presented with B2 as a sample s/he will pick A2 as a comparison. In effect, the two relations A1-B1 and A2-B2 are directly trained, but the relations B1-A1 and B2-A2 are derived without any further explicit training. If the individual concerned is then taught a second related conditional discrimination such as B1-C1/B2-C2, the number of relations that may be derived increase dramatically. In fact, it has been repeatedly demonstrated that training the two related conditional discriminations, A1-B1/A2-B2 and B1-C1/B2-C2, will result in the emergence of the following eight derived relations: B1-A1, B2-A2, C1-B1, C2-B2, A1-C1, A2-C2, C1-A1, C2-A2. If these emergent or derived relational responses are observed, the stimuli involved are said to participate in equivalence relations (Barnes, 1994; Sidman & Tailby, 1982).

Sidman's conceptualization of stimulus equivalence defines it in terms of the mathematical relations of reflexivity, symmetry, and transitivity. To fulfill this definition, an equivalence relation has to posses all three of these properties. Reflexivity requires that a subject conditionally relate each stimulus to itself, that is, "if a then a." Generalized identity matching is usually taken as evidence for this relation (but see Lane & Critchfield, 1996). Symmetry requires that the relation between stimuli be reversible, so that training "if a then b" derives "if b then a." This may be tested by reversing the roles of sample and comparison in the conditional discrimination tasks. Finally, transitivity requires that a relation between two stimuli, "if a then b," will combine with a relation between one of those stimuli and a novel stimulus, for example "if b then c," so that the relation "if a then c" emerges. A combined test for transitivity and symmetry (also referred to as a test for an equivalence relation), involves reversing the sample and comparison stimuli presented on a test for transitivity. In effect, "if a then b" and "if b then c" are trained, the relation "if c then a" should emerge (see Sidman & Tailby, 1982, for the rationale underlying the combined test for symmetry and transitivity).

Why is Stimulus Equivalence Important?

The initial excitement generated by Sidman's early studies of stimulus equivalence was due to its applied utility in teaching reading comprehension to severely developmentally disabled individuals. It was only later that the full extent of the conceptual implications of the phenomenon itself, and the methods used to examine it, became fully appreciated. Results reported in 1982 (Sidman, Rauzin, Lazar, Cunningham, Tailby, & Carrigan, 1982; Sidman & Tailby, 1982), made it clear that stimulus equivalence involved far more than a simple methodology for teaching and defining reading comprehension. In fact, the arbitrary nature of the stimuli used in equivalence research (e.g., written words, nonsense syllables, geometric shapes) suggested that it could "provide a behavioral basis for everyday correspondences between words and things, between what we say and what we do, and between rules and contingencies" (Sidman, 1994, p. 123).

Other researchers have also suggested that the bi-directional relations among stimuli involved in equivalence classes provide a basis for referential meaning (e.g., Barnes & Holmes 1991; Cullinan, Barnes, Hampson, & Lyddy 1994; Hayes & Hayes, 1992; Sidman, 1986; Wulfert & Hayes, 1988). For example, Wulfert and Hayes (1988) pointed out that if a child is taught to point to a picture of a dog when hearing the word "dog" (A-B), and to the written word DOG when shown the picture of a dog (B-C), the three stimuli (spoken word, written word, and picture) may then come to participate in an equivalence relation, and in some circumstances will be functionally substitutable. Therefore, the word "dog" is symbolic of the referent (i.e., an actual dog), and the referent is the meaning of the word. Many of the early contemporary studies of stimulus equivalence successfully used such stimuli and procedures with a variety of subject populations (e.g., Dixon & Spradlin, 1976; Sidman, 1971; Sidman, Kirk, & Willson-Morris, 1985; Sidman & Tailby, 1982; Spradlin & Dixon, 1976). Additionally, equivalence procedures have also been used successfully to establish language training and reading programs (e.g., de Rose, de Souza, Rossito, & de Rose, 1992; see also Stromer, 1991).

Since the late 1980's, the study of stimulus equivalence has been linked directly to the behavior analysis of human language in a variety of contexts. For example, Barnes (1994) outlined five areas of research that provide evidence to support the view that stimulus equivalence and human language are closely interrelated. First, equivalence has not been demonstrated unambiguously by nonhumans or by humans who are not verbally-able (e.g., Barnes, McCullagh, & Keenan, 1990; Devany, Hayes, & Nelson, 1986; Hayes, 1989; Dugdale & Lowe, 2000; Lionello-DeNolf & Urcuioli, 2002; Lipkens, Kop, & Matthijs, 1988; Sidman et al., 1982). Second, learning to name stimuli may facilitate equivalence responding in young children (Dugdale & Lowe, 1990; Eikeseth & Smith, 1992). Third, equivalence procedures can be used to treat language deficits in verbally-disabled individuals (e.g., Cowley, Green, & Braunling-McMorrow, 1992; deRose, et al., 1992; Matos & d'Oliveira, 1992). Fourth, equivalence phenomena have been used to develop a behavior-analytic interpretation of both symbolic meaning and the generative nature of grammar (e.g., Barnes-Holmes, Barnes-Holmes, & Cullinan, 2000; Barnes & Hampson, 1992; Barnes & Holmes, 1991; Cullinan, Barnes, Hampson, & Lyddy, 1994; Hayes & Hayes, 1989: Sidman, 1992; Wulfert & Hayes 1988). Fifth, equivalence procedures have been used to examine highly verbal human behaviors such as social categorization (Kohlenberg, Hayes, & Hayes, 1991; Roche & Barnes, 1996; Watt, Keenan, Barnes, & Cairns, 1991) and logical reasoning (Barnes & Hampson, 1992; Barnes, Hegarty, & Smeets, 1997; Lipkins, 1992). In addition to these five areas of research, identified by Barnes (1994), more recent findings in the neuroscience literature have shown that brain activation patterns produced during the formation of equivalence relations (recorded using fMRI) resemble those involved in semantic processing underlying language (Dickins, Singh, Roberts, Burns, Downes, Jimmieson, & Bentall, 2001; see also, Staunton, Barnes-Holmes, Whelan, Barnes-Holmes, Stewart, Dymond, & Smeets, this volume). Overall, therefore, the evidence for a close relationship between equivalence relations and human language is substantive at this stage.

On balance, two issues are worth nothing. First, a few studies have reported equivalence class formation in non-verbal organisms (e.g., Shusterman & Kastak, 1993; Kastak, Schusterman, & Kastak, 2001; Kastak & Schusterman, 2002). In each case, however, one of the two participants had previously been exposed to a form of multiple-exemplar training in which numerous sets of equivalence relations were directly reinforced, and both participants had been provided with extensive training in an artificial gestural language (moreover, in one of the studies [Kastak, et al., 2001, p. 149] the critical symmetry relations were explicitly trained within the experiment). As will be argued subsequently, such extensive pre-experimental training could be interpreted as the functional equivalent of the type of language training that is required to produce the phenomenon of stimulus equivalence itself.

Second, a recent study with humans with extremely limited vocal skills reported successful demonstrations of equivalence class formation (Carr, Wilkinson, Blackman, & McIlvane, 2000). However, the participants did possess basic listening repertoires and some manual signing or picture-based augmentative communication skills. Furthermore, each of the participants had been exposed to multiple years of special education, and in some cases had participated in previous studies using MTS procedures. It is not possible, therefore, to rule out the participants' albeit limited verbal histories as an important element in the production of equivalence responding in this study.

Explaining the Relationship Between Stimulus Equivalence and Human Language

Although the relationship between stimulus equivalence and human verbal ability has stimulated behavioral research in this area, it has also introduced theoretical complexities. An empirical relationship does not indicate that equivalence relations depend upon language or that such relations are mediated by language, although some researchers have adopted that position for specific theoretical reasons (e.g., Horne & Lowe, 1996; Lowe & Horne, 1997). Nor does it indicate that language depends upon equivalence relations, although other behavioral researchers have offered this interpretation (McIlvane, Serna, Dube, & Stromer, 2000; Sidman, 1990, 1992, 1994, 2000).

When two dependent variables are correlated, one conservative strategy is to determine if both variables reflect the same basic behavioral process. In other words, perhaps the correlation between verbal abilities and equivalence relations occurs because both are forms of the same general behavioral activity. If the two areas do overlap at the level of behavioral process, then questions about human language may also be questions about derived stimulus relations, and vice versa. This is the basic theoretical and empirical research strategy that a number of behavioral researchers have adopted over the past 15 years under the rubric of RFT (see Hayes, et al., 2001). The overarching aim of this behavioral research has been to integrate a range of apparently diverse psychological phenomena including, for example, stimulus equivalence, naming, understanding, analogy, metaphor, and rule-following (e.g., Hayes 1991, 1994; Hayes & Barnes, 1997; Hayes & Hayes, 1992; see also Barnes, 1994; Barnes & Holmes, 1991; Barnes & Roche, 1996; Barnes-Holmes, Hayes, Dymond, & O'Hora, D., 2001). Relational

Frame Theory adopts the view that the core defining element in all of these, and many other inherently verbal activities, is a particular type of relational responding, and moreover that this responding is amenable to a learning or operant analysis (Hayes, et al., 2001). We will now briefly examine the main tenets of RFT, focusing in particular on its interpretation of the stimulus equivalence phenomenon.

Relational Frame Theory

Stimulus equivalence as learned behavior. Relational Frame Theory accounts for stimulus equivalence by appealing to the concept of arbitrarily applicable relational responding. The theory starts with the basic fact that many species are capable of responding to non-arbitrary relations between or among stimuli (e.g., bigger than, darker than; see Reese, 1968). The theory then postulates that a similar process may be at work in the context of derived stimulus relations (in which the stimuli involved are not related to each other along a consistent physical dimension). Suppose, for example, that a person is taught A-B and later B-A relations. With one exemplar, the specific formal properties of each relation may dominate (e.g., "given red triangle pick green square, and given green square pick red triangle"). With additional and diverse exemplars, however, the discriminative control will become increasingly refined, and there will be a gradual exclusion of an increasing number of irrelevant formal stimulus properties. As a growing number of properties are excluded, through exposure to an increasingly rich history of differential reinforcement across a variety of complex stimuli, eventually the behavior of relating itself may be discriminated (to put the abstractive process in verbal form, "given that this one is related to that one, that one must be related to this one"). The critical point here, is that RFT argues that derived relating can be brought under antecedent and consequential control, and thus specific patterns of relational responding may be conceptualized as generalized operant classes (see Barnes-Holmes & Barnes-Holmes, 2000, for a detailed discussion). In much the same way that training imitation across multiple exemplars can lead to what has been called generalized imitation in which "correspondence itself may become a factor... extending to new topographies of behavior" (Dinsmoor, 1995, pp. 264-265), training derived relating across multiple exemplars can produce an operant class in which relating itself becomes the important factor, thereby extending to novel specific instances.

Given an appropriate history of multiple exemplar training, RFT suggests that verbally-able humans are capable of responding to *arbitrary* relations between and among stimuli; that is, relations not defined by the formal properties of the stimuli involved. For example, a young child may learn to relate the word “dog” to a picture of a dog, even though there is no formal basis for the relation between the word and the picture (Luciano, Barnes-Holmes, & Barnes-Holmes, 2001). Relational frame theory argues that such a relation is based on a history of reinforcement for responding relationally to pictures with respect to words (and vice versa), and similarly to many other pairs of objects or events. That is, RFT proposes that after an appropriate history of bi-directional training across multiple exemplars, the process of relating may become abstracted so that it can be applied arbitrarily, given an appropriate context in which to do so.

According to RFT, stimulus equivalence is an instance of arbitrarily applicable relational responding, brought to bear by some aspect of the context in which the task occurs. In the above example, a young child might be shown a picture of a dog and asked to “pick the word that means this” from an array of words. Given an appropriate history of relational training, some features of the context, such as the MTS format, or the words “means this”, will bring to bear that history and result in “correct” responding. The term “relational framing” is used to denote this behavioral class (Barnes-Holmes & Barnes-Holmes, 2000). As an aside, the RFT focus on previous relational and verbal histories, as the basis for explaining stimulus equivalence, is entirely consistent with those studies that have reported equivalence class formation in sea lions, or language-impaired humans, who have been exposed to extensive relational or artificial language training (e.g., Carr, et al., 2000; Shusterman & Kastak, 1993; Kastak, et al., 2001; Kastak & Schusterman, 2002).

Defining relational frames. According to RFT, stimulus equivalence is one example of a relational frame of coordination, and the properties of stimulus equivalence such as reflexivity, symmetry, and transitivity are instances of arbitrarily applicable relational responding. Nevertheless, RFT is broader in scope than the equivalence phenomenon and thus a new set of terms is required to define relational frames. The term mutual entailment, for instance, encompasses symmetrical responding but also refers to responding that cannot be considered strictly symmetrical. For example, in a frame of coordination, if A is the same as B, then B is the same as A; that is, the relation is symmetrical. In a comparative frame, however, if A is better than B, then B is worse than A. The relations are not strictly symmetrical but they are mutually entailed.

Similarly, the term combinatorial entailment encompasses transitivity, but also refers to relations that cannot be described as transitive. For example, transitive responding in the context of a frame of coordination would entail that if A is the same as B, and B is the same as C, then A is the same as C. However, in the case of a frame of opposition, if A is the opposite of B, and B is the opposite of C, then the relation between A and C is one of sameness, not opposite. Therefore, the relations are not strictly transitive, but they are combinatorially entailed; that is, the relations between A and B and between B and C combine to entail the relations between A and C and between C and A. According to RFT, therefore, both transitivity and equivalence responding are instances of combinatorial entailment in which the trained relations are the same as the derived relations.

An alternative term that captures the property of reflexivity does not appear to be necessary. Furthermore, some researchers have questioned the utility of reflexivity as a defining property of derived relational responding because such responding may be based upon either derived stimulus relations or formal similarity (Steele & Hayes, 1991; see also Barnes, 1994). In any case, this issue is not important in the context of the current article and thus requires no further discussion.

The final defining feature of RFT is a transfer or transformation of functions. When stimuli are involved in a relational frame, any psychological function attached to one of those stimuli, may transfer through the relational frame to any or all of the other stimuli involved. If the relevant frame is one of coordination, then a similar function will attach to each stimulus in the frame (e.g., Barnes & Keenan, 1993; Barnes-Holmes, Keane, Barnes-Holmes, & Smeets, 2000; Dymond & Barnes, 1994; Visdómine & Luciano, 2002; Wulfert & Hayes, 1988). For example, if a child learns to stop talking when a teacher says “quiet” and this word participates in a relational frame of coordination with the Irish word "ciunas," then the child may stop talking when the teacher says "ciunas." For RFT, this effect is due to the function of the word “quiet” transferring to the word "ciunas" through the derived relation between the English and Irish words. If, however, the relational frame is not one of coordination the functions will be *transformed* in accordance with the relational frame involved. For example, if two stimuli participate in a frame of comparison, such that stimulus A is “more than” stimulus B, and B is established as discriminative for a low-response rate, A may acquire a discriminative function for a high response rate based on its “more than” relation with A (see Dymond & Barnes, 1995, for empirical evidence). In this case, the low-rate function of B does not transfer to A -instead it is *transformed* in accordance with the comparative relation between the two stimuli.

The importance of contextual cues. As pointed out previously, RFT suggests that equivalence responding is typically controlled by particular contextual cues, such as the MTS format itself. In fact, RFT argues that all mutually and combinatorially entailed relations are under some form of contextual control. Without such control, different patterns of relational responding could not be observed. For example, in teaching a child to identify the same type of stimulus in one instance and a different type of stimulus in another, specific cues must be presented to differentiate the appropriate responses (e.g., “show me the *same* one versus show me a *different* one”). In this case, the words, *same* and *different* come to function as the relevant contextual cues, and thus two patterns of relational responding are established and maintained. Contextual control is also critical for the transfer or transformation of functions. For example, if *all* functions of one stimulus in an equivalence relation transferred to another, then the two would merge and the stimuli would be indistinguishable in a psychological sense -- theoretically, a person would attempt to eat the word “steak” or drive the word “car.” This does not occur because the transfer of functions is also under the control of contextual stimuli (e.g., Barnes, Browne, Smeets, & Roche, 1995; Roche, Barnes-Holmes, Smeets, Barnes-Holmes, & McGeedy, 2000; Wulfert & Hayes, 1988). In fact, important sources of contextual control in this regard are the physical properties of the related events. For example, a young child who attempts to eat a piece of paper with the word "candy" written on it, soon learns that the word and the actual substance do not share the same physical properties.

The importance of physical properties in the natural environment, as possible sources of contextual control over patterns of relational responding, is heavily emphasized in RFT. To appreciate why, complete the following exercise (based on Hayes, 1994). Think of any two concrete nouns – any nouns will do - before reading the next sentence. Let us call the first noun "A" and the second "B". Now answer the following questions: How are "A" and "B" alike? How are they different? How might "A" be better than B?

How might "B" be the daughter of "A"? Whenever this exercise is conducted in conference settings, at least some members of the audience can provide answers to every one of these relational questions, and many others like them, and these answers are typically justified by the supposed formal properties of the related events. If, for example, you thought of “Kangaroo” and “Chair,” the first question could be answered by pointing to the fact that a young kangaroo sits in the adult’s pouch. The critical point here, however, is that these types of formal properties would rarely control the nonarbitrary-relational responses of nonverbal organisms. In other words, *the formal properties used to "justify" the relational responses to the types of questions listed above are themselves abstracted as a result of these same relational activities*.

According to RFT, therefore, formal or non-arbitrary relational properties may function as contextual cues for a previously established repertoire of arbitrarily applicable relational responding. This type of control should not be confused with primary stimulus generalization, and other forms of *direct* relational stimulus control (Reese, 1968), for which no prior history of relational framing is required. The distinction between direct relational stimulus control and non-arbitrary relational contextual cues is thus a functional one, in that functionally distinct behavioral histories are involved in producing these two types of stimulus control. It should also be noted that stimulus equivalence, as studied in the behavioral laboratory, is an example of relational framing that is largely unconstrained by the formal properties of the events that participate in the equivalence relations. We shall return to this issue at a later point in the article.

Summary. Relational Frame Theory suggests that stimulus equivalence is a special case of arbitrarily applicable relational responding or relational framing. As such, equivalence is produced primarily through exposure to the contingencies of reinforcement operating within a verbal community. Furthermore, equivalence is not a unique phenomenon, but is simply the most basic and fundamental of a potentially limitless number of arbitrarily applicable relations.

Stimulus equivalence and relational frame theory: Procedures, data, and interpretation

Stimulus equivalence and RFT have generated a considerable body of empirical and conceptual analyses, and of course many issues remain unresolved (see Hayes, et al., 2001; Sidman, 1994). What is remarkable, however, is that so much theoretical speculation has emerged from work with just one procedure -- MTS. Typically, in behavior analysis our concepts are transituational (Barnes-Holmes, Dymond, Roche, & Grey, 1999). For example, reinforcement, discrimination, primary stimulus generalization, respondent conditioning, and other principles are not defined in relation to a particular procedure (e.g., training in a Skinner box). Any of the foregoing terms refer to behaviors that have been examined in a wide variety of both basic and applied settings. This is not the case for stimulus equivalence. There are only a few published studies that have attempted to break free of MTS in the study of equivalence relations (e.g., Cullinan, Barnes, & Smeets, 1998; Cullinan, Barnes-Holmes, & Smeets, 2000, 2001; Fields, Reeve, Varelas, Rosen, & Belanich 1997). The research described in the latter half of the current article was based on the assumption that we will learn more about the phenomenon of stimulus equivalence and derived stimulus relations more generally, if we start to break free of the MTS format. If the concept of stimulus equivalence is a valuable one, and has a direct bearing on human language and cognition, as many have suggested, then it should be possible to study it in a variety of contexts. If not, then stimulus equivalence is nothing more than a behavior-analytic curiosity destined for the graveyard of irrelevant behavioral effects (see Barnes-Holmes, Hayes, & Roche, 2000; Pilgrim & Galizio, 1996, for a similar arguments). We should stress, however, that MTS has been, and will likely remain, an extremely useful and powerful methodology for studying derived stimulus relations. Our aim here is simply to encourage researchers in the field to extend the range of experimental preparations that we currently employ in this area of investigation.

Variations on Matching-To-Sample

There have been attempts to extend the range of methods used to study stimulus equivalence by using variations of the standard MTS procedure. For example, complex stimuli have been used in identity and arbitrary MTS (see Markham & Dougher, 1993; Schenk, 1993; Smeets, Schenk, & Barnes, 1994; Smeets, & Striefel, 1994; Stromer, McIlvane, & Serna, 1993). A complex stimulus is made up of more than one element; for example, a color superimposed on a form. Using complex stimuli as either samples or comparisons in MTS training allows for testing of the relations between the elements of each complex stimulus, as well as between the complex stimuli and other single element stimuli. For example, a complex sample and single element comparison could be used to train the relation AB->C (e.g., colour-form sample and form only comparison). Some of the relations that might be generated by this training are A->B, A->C, and B->C. In general, these studies have shown that matching to complex stimuli generates conditional relations between the elements of the complex stimulus, as well as between those complex stimuli and other single element stimuli. In some cases the emergent relations observed using complex stimuli have been characterized as equivalence relations (but see Stromer et al., 1993).

Another variation of MTS was a modified successive conditional discrimination procedure used by Dube, Green, and Serna (1993) to demonstrate equivalence using auditory stimuli (cf. Wasserman, 1976). Each trial of this procedure involved the auditory presentation of four digitized nonsense syllables; first a sample followed by one comparison, then the sample again followed by the alternative comparison. During the presentation of each auditory comparison, a portion of the computer screen was illuminated (a different illuminated box represented each different comparison). After completion of sample and comparison presentations, the illuminated boxes representing each comparison were presented concurrently and subjects responded by selecting one of the illuminated boxes.

Other researchers have also developed alternative procedures for examining equivalence, but all of these can be interpreted as variations of MTS. For example, a constructed response procedure has been used in which a sample is presented along with a pool of letters that may be selected, in sequence, to construct words (Calcagno, Dube, DeFaria Galvao, & Sidman, 1994; Dube, McDonald, McIlvane, & Mackay, 1991; Mackay & Sidman, 1984). In such a procedure, once the sample has been presented the first letter of the matching word may function as the positive comparison and all other letters function as negative comparisons. Similarly, once the first letter has been selected, the next letter of the matching word functions as a positive comparison and all remaining letters function as negative comparisons, and so on.

Similarly, a sequence training procedure, which has been widely used (e.g., Lazar, 1977; Lazar & Kotlarchyk, 1986; Sigurdadottir, Green, & Saunders, 1990; Stromer & Mackay, 1993), and is also known as simultaneous chaining (Terrace, 1983; Terrace, Straub, Bever, & Seidenberg, 1977), can be interpreted in the same way. Specifically, once the first stimulus is selected, the next stimulus in the sequence functions as the positive comparison and all remaining stimuli function as negative comparisons. Once the second stimulus has been selected, the next in the sequence functions as the positive comparison and all remaining stimuli function as negative comparisons, and so on.

Breaking Away From Matching-to-Sample: The Respondent-Type Training Procedure

Three of the current authors (DBH, PMS, & GL) developed a training procedure that does not involve MTS, but reliably generates emergent or derived matching performances in the context of a MTS test (Barnes, Smeets, & Leader, 1996; Leader, Barnes, & Smeets, 1996; Leader, Barnes-Holmes, & Smeets, 2000; Smeets, Leader, & Barnes, 1997). The basic procedure involves presenting an arbitrary stimulus, A, that reliably predicts the appearance of a second arbitrary stimulus, B (i.e., A->B; note that A and B are never presented simultaneously). Following sufficient exposure to this respondent-type[2] training procedure, a subject is given the opportunity to pick stimulus A (as a comparison) in the presence of stimulus B (as a sample) on a MTS task. In effect, having been exposed to A->B respondent training does the subject respond in accordance with the B-A symmetry relation? Furthermore, if stimulus A always precedes B and B always precedes C in a respondent training procedure (A->B->C), will the subject respond in accordance with the C-A equivalence relation on a MTS test? The development of this procedure raised some interesting conceptual issues in relation to the phenomenon of stimulus equivalence, and so we will briefly review part of the study reported by Leader et al. (1996).

The first study conducted using the respondent-type training procedure, involved three conditions (only the first two are relevant in the current context). In Condition 1, five subjects (experimentally naïve undergraduates) were provided with detailed instructions that specified that the first part of the experiment (the respondent-type training) was related to the second part (the equivalence test): "During the first stage of this experiment you will be presented with nonsense syllables on the computer screen. You should pay close attention to this first stage because it is relevant to the second stage of the experiment." The five subjects were exposed to a respondent-type training procedure in which six stimulus pairs (A1->B1, B1->C1, A2->B2, B2->C2, A3->B3, B3->C3) were presented on a computer screen (i.e., no overt observing responses were required, and no measures were taken to ensure that the subjects attended to the stimuli). A 0.5 s 'inter-stimulus interval' separated the stimuli in each pair, and a 3 s 'inter-pair interval' separated the presentation of stimulus pairs. All six stimulus pairs were presented in this fashion, in a quasi-random order for sixty trials, the only constraint being that each stimulus pair was presented once in each successive block of six trials (i.e., each stimulus pair was presented 10 times). All stimuli were randomly selected nonsense syllables.

Following the respondent-type training, the subjects were exposed to a three-choice MTS procedure that tested for the six symmetry relations (i.e., B1-A1, B2-A2, B3-A3, C1-B1, C2-B2, C3-B3) and the three equivalence relations (C1-A1, C2-A2, C3-A3). The computer presented the nine MTS tasks and recorded the subjects' responses; no feedback was presented during the equivalence test. The nine relations were tested in a quasi-random order for 90 trials, the only constraint being that each of the nine tasks occurred once within each block of nine trials. A consistency criterion was used that required each subject to choose the same but *not necessarily correct* comparison at least 9 times out of 10 on each of the 9 tasks ("correct" will be used to describe responses that are in accordance with the symmetry and equivalence relations). This consistency criterion was used to control for the effects of inadvertent feedback provided by repeated training and testing (see Barnes & Keenan, 1993, p. 63, for rationale), and had been used successfully in a number of previous studies (e.g., Dymond & Barnes, 1995; 1996; Roche & Barnes, 1996). If a subject produced an inconsistent performance (i.e., less than 9 out of 10 "same responses" on any of the tasks) he or she was immediately reexposed to the entire experimental procedure again (i.e., respondent training and equivalence testing). If a subject did not produce a consistent performance by the fourth exposure to the entire experimental sequence, *and* his or her performance was less than 50 percent correct (i.e., the subject produced fewer than 45 correct responses), the performance was classified as inconsistent and the subject's participation in the study was terminated. If, however, a subject produced more than 50 percent correct responding on a fourth exposure to the equivalence test, additional exposures to the training and testing were provided until he or she either produced fewer than 50 percent correct responses or produced a consistent performance. This criterion thereby ensured that a subject who produced an inconsistent performance, that was considerably higher than chance (i.e., 33% correct), would not be prevented from retraining and retesting.

In Condition 2, an additional five subjects were exposed to the same procedures, except that they were given minimal instructions at the beginning of the respondent training (i.e., "Look at the screen") that did not specify a relationship between the first and second parts of the experiment (all remaining conditions also used minimal instructions). This condition allowed us to determine if specifying a link between respondent-type training and MTS testing, facilitates, suppresses, or does not affect the emergence of equivalence responding (cf. Green, Sigurdardottir, & Saunders, 1991; Sigurdardottir, Green, & Saunders, 1990; Saunders, Saunders, Williams, & Spradlin, 1993).

Eight out of the 10 subjects produced almost perfect equivalence responding. Two subjects showed a consistently incorrect performance on their third and second exposures respectively, and thus their participation in the study was terminated. Six exposures was the maximum required and two was the minimum. These data clearly showed that the respondent-type training procedure, combined with either detailed or minimal instructions, reliably generates equivalence responding in the absence of explicit MTS training in the experimental context. Further studies have since shown that the respondent-type training procedure may also be used effectively with young children (e.g., 5 years old), using four-member classes, different training designs; (i.e., sample-as-node and comparison-as-node), and fractions and decimals as stimuli (Leader, Barnes-Holmes, & Smeets, 2000; Leader & Barnes-Holmes, 2001; Smeets, Leader, & Barnes, 1997).

Perhaps the most remarkable feature of this research with the respondent-type training procedure is that explicit, differential reinforcement was never provided for selecting any of the stimuli in a MTS context. Previous research has shown that learning disabled individuals, and normally developing children, may demonstrate the merger and development of equivalence relations based on the unreinforced conditional selection of comparison stimuli *following a history of explicitly reinforced matching-to-sample responding and successful equivalence testing* (Saunders, Saunders, Kirby, & Spradlin, 1988; Williams, Saunders, Saunders, & Spradlin, 1995). In the Saunders et al. study, for example, subjects were first trained and tested for the formation of equivalence relations, and were then allowed to choose (in the absence of differential reinforcement) which novel comparisons "went with" the previously trained samples. Having done so, the subjects consistently related the novel comparisons in a 'relation-consistent-manner' to the remaining stimuli participating in the previously established equivalence relations. The respondent-type training procedure, however, demonstrated reliable equivalence responding without an experimental history of explicit differential reinforcement for MTS responding, and without an experimental history of successful equivalence testing. How might we explain this outcome?

Relational Frame Theory: An interpretation of the respondent-type training procedure. As outlined earlier, according to RFT, emergent performances such as equivalence are normally produced, in part, by the subject's history of arbitrarily applicable relational responding that is brought to bear by various contextual cues on the MTS test (see Barnes & Holmes, 1991; Barnes, 1994; 1996; Barnes & Roche, 1996; Hayes, 1991, 1994; Hayes & Hayes, 1989; 1992). From this perspective, learning to name objects and events in the world constitutes one of the earliest and most important forms of arbitrarily applicable relational responding. For instance, parents often utter the name of an object in the presence of their young child and then reinforce any orienting response that occurs towards the named object. This interaction may be described as, hear name A -> look at object B. Parents also often present an object to their young child and then model and reinforce an appropriate "tact" (Skinner, 1957). This interaction may be described as see object B -> hear and say name A (see Barnes, 1994, for a detailed discussion). Initially each interaction may require explicit reinforcement for it to become firmly established in the behavioral repertoire of the child, but after a number of exemplars have been trained, derived "naming" may be possible. Suppose, for example, a child with this naming history is told "This is your shoe." Contextual cues, such as the word "is" and the naming context more generally, may establish symmetrical responding between the name and the object. Without further training, for example, the child will now point to the shoe when asked "Where is your shoe?" (name A -> object B) and will utter "shoe" when presented with the shoe and asked "What is this?" (object B -> name A).

Arbitrarily applicable relational responding may be brought to bear on any stimuli, given appropriate contextual cues. Relational Frame Theory therefore explains equivalence responding in terms of a training history applicable to a given situation. In effect, when a young child is taught a number of name-object and object-name relations and is then exposed to a MTS procedure, contextual cues provided by this procedure may be discriminative for equivalence responding. In fact, the MTS format itself may be a particularly powerful contextual cue for equivalence responding, insofar as it is often used in preschool education exercises to teach picture-to-word equivalences (see Barnes, 1994, and Barnes & Roche, 1996, for detailed discussions).

How then might RFT account for the respondent data? In addition to naming, children are normally taught that events that are correlated in time and/or space often "go together" (i.e., participate in equivalence relations). In a typical early education exercise, for example, a child might learn that a picture of a dark cloud and the words "dark cloud" should be matched to a picture of rain and to the word "rain." In effect, the temporal and spatial correlation of actual dark clouds and rain is used to establish, in certain contexts, an equivalence relation between these events and the arbitrary stimuli "dark cloud" and "rain." After sufficient training of this type, a child might respond, in certain contexts, to other correlated events as participating in equivalence relations in the absence of explicit reinforcement. For example, having established an equivalence relation between actual lightening and the word "lightening" and another equivalence relation between actual thunder and the word "thunder", given an appropriate context (e.g., when asked by a teacher about different types of weather), the child might say "thunder and lightening go together" (see Figure 1). In effect, the correlation between lightening and thunder in the natural environment is sufficient to establish an equivalence relation between these events and their descriptors if; (a) the child has an appropriate history of arbitrarily applicable relational responding, and (b) is provided with an appropriate context (i.e., a question about types of weather from a teacher).

From the RFT perspective, therefore, the temporal correlations that occurred among the stimuli during the respondent-type training produced equivalence responding, in part, because; (a) the subjects all possessed the appropriate histories of arbitrarily applicable relational responding, and (b) these histories were brought to bear by various contextual cues provided by the experimental setting and procedure. At the present time, of course, it is not possible to identify exactly what properties of the experimental environment functioned as contextual cues, but a likely source of contextual control for equivalence responding was the MTS format of the equivalence test itself (see two

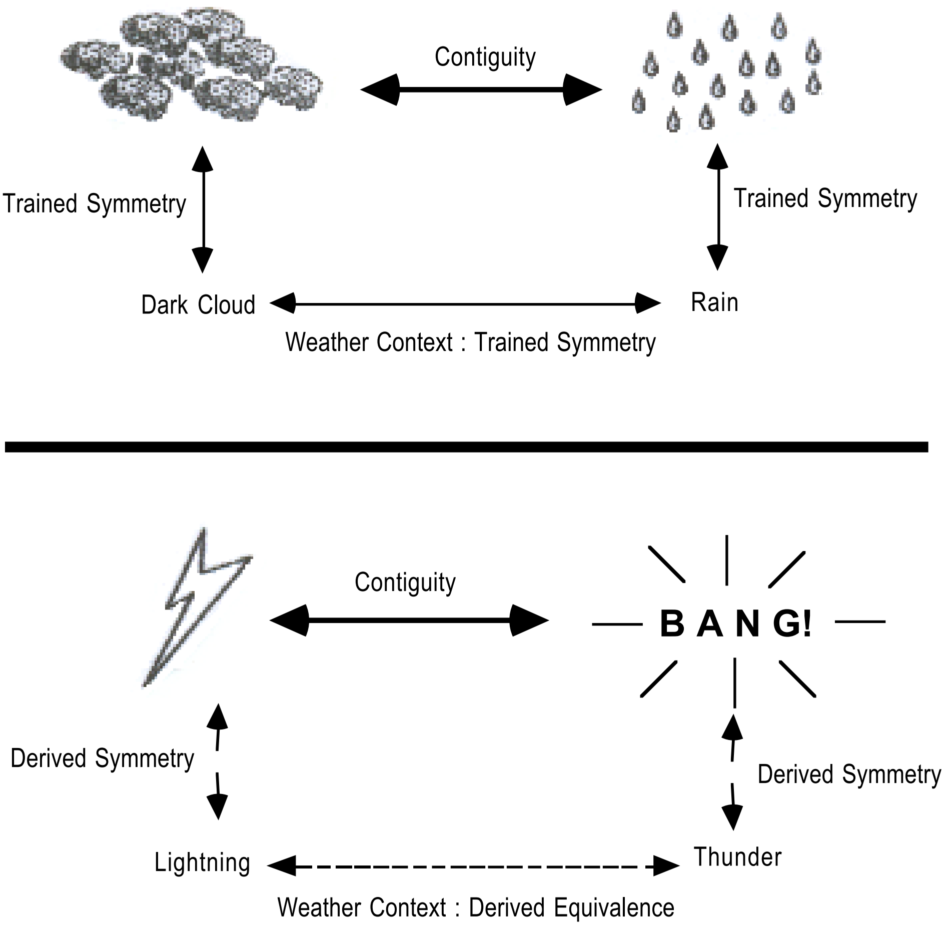

Figure 1 Diagrammatic representation of how spatial and temporal contiguity may come to function as a contextual cue for equivalence relations.

paragraphs above, and see Barnes, 1994; Barnes & Roche, 1996). More informally, exposure to the MTS tasks may have helped subjects to discriminate that the respondent training was being used to "tell them which stimuli go together," and that the MTS tasks were being used to determine if they had "*learned* which stimuli go together."

Of course, the foregoing RFT explanation is largely interpretive, and whether this or some other explanation proves to be the most adequate will depend upon further research with both the respondent-type and other procedures. Nevertheless, the development of the respondent-type procedure, and the interpretation of its effects using RFT, has served to highlight a possibly important contextual cue -- temporal and spatial correlations -- for the formation of equivalence classes. It should be noted, however, that very recent unpublished data from the Maynooth RFT laboratory indicates that such correlations do not always function as cues for equivalence relations.

The study in question involved using the respondent-type training procedure to establish two five-member equivalence classes of a linear design (e.g., A1->B1, B1->C1, C1->D1, D1->E1). During the MTS equivalence tests, some of the subjects responded correctly during all transitivity probes (e.g., A1-C1, A1-D1, A1-E1, etc.), but incorrectly during all equivalence probes (i.e., C1-A2, D1-A2, E1-A2, etc.). This pattern of responding during equivalence tests is quite unusual, and had not been observed before with the respondent-type training procedure, and thus warranted careful scrutiny. Upon further investigation, it emerged that some of the participants were not experimentally naive and had actually participated in an earlier study in which the temporal sequencing of stimulus pairs on a computer task was used to establish contextual cues for Before and After relations (O'Hora, Barnes-Holmes, Roche, & Smeets, in press). Thus, when the participants were exposed to the respondent-type training procedure, the temporal sequencing of the stimulus pairs continued to function in this way. That is, the unusual response patterns observed on the equivalence tests are readily predicted based on Before/After contextual control (e.g., if A1 is before B1 and B1 is before C1, then A1 is before C1, but C1 is NOT before A1). A systematic study of this effect is currently being conducted.

The development of the respondent-type training procedure, and the careful analysis of both expected and unexpected results obtained from it, serves to highlight the heuristic value in exploring alternative methodologies. Applying different experimental preparations can direct our attention to sources of control that have received scant attention within the literature on derived relations. Moreover, such work may tell us something about the controlling variables that are operating in the more typical MTS procedures, and thus help us understand the behavioral processes involved in equivalence class formation and derived relations more generally. It was in this spirit that we developed what we call the precursor to the Relational Evaluation Procedure (pREP), and it is to this topic that we now turn.

The Precursor to the Relational Evaluation Procedure

As described previously, the respondent-type procedure does not involve MTS training, but it does involve MTS testing. One aim that arose from this research was to develop an experimental preparation that could be used to train and test for equivalence responding without employing a traditional MTS procedure. One such procedure is referred to as go/no go, and has been reported extensively in the animal learning literature. A typical go/no-go procedure (e.g., D'Amato & Colombo, 1985) involves the presentation of two stimuli on each trial, one conditional stimulus (CS) and one discriminative stimulus (Sd). On trials in which a CS is presented with a positive Sd, responding is reinforced, and on trials in which a CS is presented with a negative Sd, responding is extinguished. Responding would typically involve pressing a response key within a specified time (e.g., 3 s) after termination of the comparison presentation.

Go/no-go procedures have been used to study a variety of topics across different animal populations. For example, with rats such procedures have been used to study odor discriminations (Gheusi, Goodall, & Dantzer, 1997), odor generalization (Duncan, Beauchamp, & Yamazaki, 1992), auditory discrimination (Neill & Harrison, 1987; Dube, Callahan, & McIlvane, 1993), and response inhibition (Reed & Pizzimenti, 1995). Similarly, with pigeons go/no-go procedures have been used to examine object representation (Warner & Rilling, 1997), mental rotation (Hamm, Matheson, & Honig, 1997), object perception (Cook & Katz, 1999), categorical discrimination (Jitsumori & Yoshihara, 1997) and short-term memory (Wasserman, Grosch, & Nevin, 1982).

Other procedures have been developed that are quite similar to the go/no-go procedure. For example, go left/go right, or yes/no (e.g., D'Amato & Worsham, 1974), or same/different (Edwards, Jagielo, & Zentall, 1982) procedures have been employed. In a review, Fields et al., (1997) outlined the wide variety of psychological phenomena that have been examined using these methodologies. For example, yes/no procedures have been used to study stimulus priming (Balota & Lorch, 1986; McNamara & Altarriba, 1988; McNamara & Healy, 1988), the scaling of time or stimulus similarity (Wearden, 1995; Fetterman & Killeen, 1995), categorization in birds (Honig & Matheson, 1995), and the formation of stimulus classes of "same" and "different" with primates (Neiworth & Wright, 1994; Wright, Santiago, & Sands, 1984; Wright, Shyan, & Jitsumori, 1990) and pigeons (Cook, Cavato, & Cavato, 1995; Edwards, Jagielo, & Zentall, 1982; Wasserman, Hugart, & Kirkpatrick-Steger, 1995).

During the course of our own research in this area, Fields et al. (1997) developed a novel method for studying stimulus equivalence based on stimulus pairing, yes/no procedures. On each experimental trial one conditional stimulus and either a positive or a negative discriminative stimulus was presented successively on a computer screen. Subjects (adult humans) were required to press a key marked with the word YES on CS-positive/Sd trials, and to press a key marked with the word NO on CS-negative/Sd trials. The instructions given to subjects were quite explicit, in that they were told to "discover whether the words go together." They were also given pre-experimental "keyboard familiarization" training using the stimulus pairing task with either semantically related words or semantically unrelated words. Using these procedures, Fields et al. (1997) found that 10 out of 18 subjects demonstrated responding in accordance with equivalence relations, without any exposure to MTS procedures. Since demonstrating that their stimulus pairing, yes/no procedure could produce equivalence, in just over 50% of their subjects, Fields and his colleagues have not published any further studies using this methodology.

Initially, our own approach to this area of research involved identifying a procedure that could be used potentially both to train conditional discriminations, and to test for emergent performances, and then to adapt the procedure so that it could be used to study equivalence responding in adult human subjects. The resulting methodology has been labeled the precursor to the Relational Evaluation Procedure (pREP). With this procedure a subject does not choose a comparison that "goes with" a sample, but rather chooses a response option that *evaluates* the positive or negative *relation* that obtains between the CS and Sd stimuli on a given trial. This basic methodology has been developed and extended over the years and has been labeled the Relational Evaluation

Procedure (REP) (Barnes-Holmes, Healy, & Hayes, 2000; Hayes & Barnes, 1997; O'Hora, Barnes-Holmes, Roche, & Smeets, in press; Stewart, Barnes-Holmes, & Roche, in press). The go/no-go procedures discussed in the current article were instrumental in the development of the REP, and thus the prefix *precursor* has been used to denote this fact.

In the original pREP, each trial consisted of the presentation of one CS followed by either a positive or a negative Sd, with a go/no-go response requirement on each trial. In effect, subjects were trained to press the space bar of a computer keyboard on “correct” trials (i.e., when the CS was followed by the pre-designated positive Sd), and not to press the space bar on “incorrect” trials (i.e., when the CS was followed by a negative Sd). In relation to MTS, pressing the space bar on the pREP could be seen as analogous to selecting a comparison in a MTS context, and not pressing on the pREP as analogous to not selecting a comparison in MTS. In the pREP, therefore, positive and negative "sample-comparison" (i.e., CS-Sd) relations are demonstrated on separate trials.

Initially, we assumed that this first version of the pREP would be readily effective in achieving the goals of our research, but it quickly became apparent that this was not the case. The next section of the current article documents our systematic exploration of why the procedure failed to work. In so doing, some interesting features of the stimulus equivalence effect emerged, and in particular the role of MTS in the demonstration of stimulus equivalence in the laboratory was highlighted. Additionally, evidence was gathered to support the RFT view of stimulus equivalence as an instance of responding in accordance with sameness relations. If nothing else, our work clearly demonstrates the value in exploring different procedures for analyzing what appears to be an important behavioral effect.

Three studies using the pREP. To date, we have published three separate studies using the pREP (Cullinan, Barnes, & Smeets, 1998; Cullinan, Barnes-Holmes, & Smeets, 2000, 2001). Broadly similar procedures have been employed across each of these studies, and so we will start by outlining the basic procedure employed in the first study, and then describe in general terms the research program that followed.

In the study reported by Cullinan et al. (1998), 20 undergraduates were randomly assigned to one of the four experiments (i.e., 5 subjects in each experiment). The stimuli used were nonsense syllables and are represented here by the alphanumerics A1, B1, C1, A2, B2, C2. Stimuli were presented on a computer, and subjects responded by pressing various marked keys on the keyboard. The overall experimental design involved each subject being trained in a series of conditional discriminations using *either* a standard MTS procedure, or the pREP. All subjects were trained in the following relations: A1->B1, A2->B2, B1->C1, B2->C2, irrespective of the training procedure to which they were exposed. When a subject reached a predetermined training criterion, he or she was tested for the emergence of symmetry (B1->A1, B2->A2, C1->B1, C2->B2) and equivalence (C1->A1, C2->A2) responding, with both trial types (i.e., symmetry and equivalence) mixed in each block of test trials. All subjects were presented with *both* standard MTS tests, *and* pREP tests. Baseline conditional discriminations were retrained (to criterion) before *each* test in each of the four experiments.

In both training and testing phases of the pREP, the CS stimulus appeared in the center of the screen for 1 s, the screen then cleared for 1 s, and either a positive or negative Sd stimulus was presented for 1 s. There was then a 5 s response interval during which the subject was required either to press the space-bar, or not press the space-bar. If the subject pressed the space-bar the response interval was immediately terminated and either the programmed consequences were presented (in training phases), or the next trial was presented (in test phases). Training trials were presented in blocks of 40 trials with each of the 8 tasks (A1->B1, A1->B2, A2->B1, A2->B2, B1->C1, B1->C2, B2->C1, B2->C2) presented five times in a quasi random order. Test trials were presented in blocks of 120 trials, with each of the 12 tasks (B1->A1, B1->A2, B2->A1, B2->A2, C1->B1, C1->B2, C2->B1, C2->B2 [symmetry]; C1->A1, C1->A2, C2->A1,

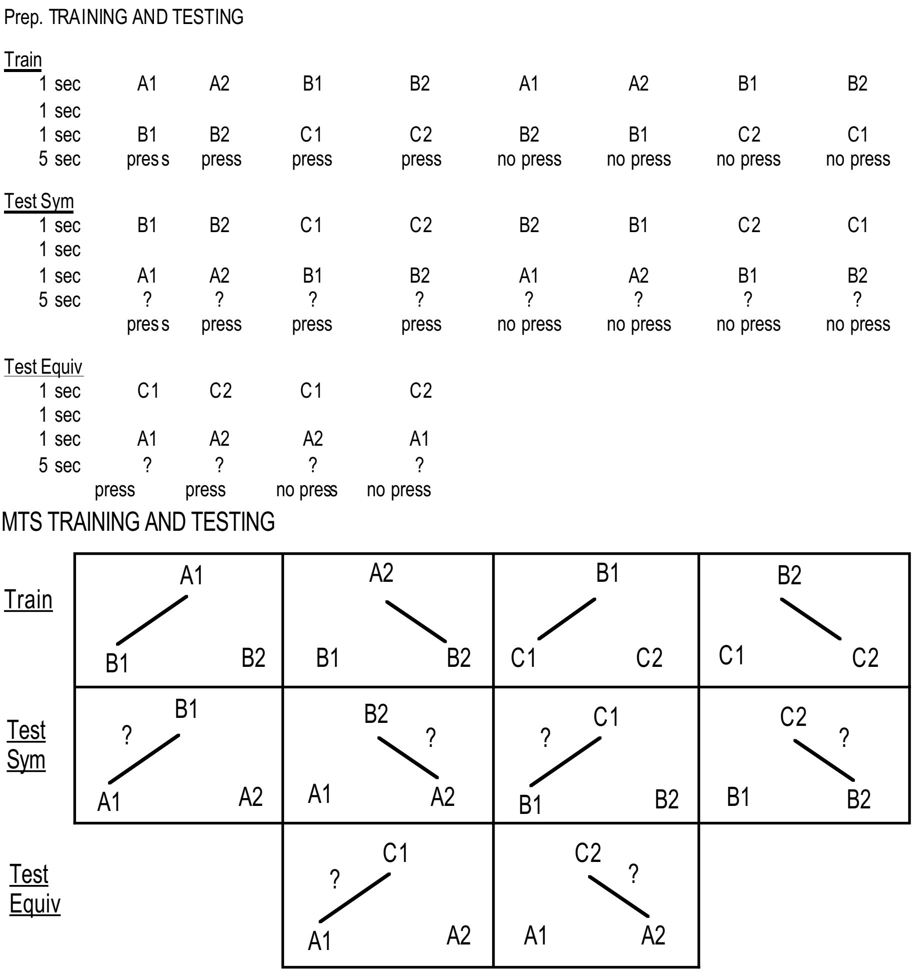

Figure 2 Schematic representation of training and testing tasks used in the MTS procedure and the pREP reported in Cullinan et al. (1998).

C2->A2 [equivalence]) presented 10 times in a quasi-random order (see Figure 2).

In both training and testing phases using the MTS procedure, the sample stimulus was presented near the top of the screen, followed 1 s later by two comparison stimuli presented to the left and right of the sample along the lower edge of the screen. All three stimuli remained visible on the screen until the subject made a response. Subjects responded by pressing one of two marked keys (Z and M) on the keyboard. During training phases, a response was followed by presentation of programmed consequences; during testing there were no programmed consequences. Training trials were presented in blocks of 40 trials with each of the 4 tasks (A1->B1/B2, A2->B1/B2, B1->C1/C2, B2->C1/C2) presented 10 times in a quasi random order, with the position of comparison stimuli counterbalanced across trials. Test trials were presented in blocks of 60 trials with each of the 6 tasks (B1->A1/A2, B2->A1/A2, C1->B1/B2, C2->B1/B2 [symmetry], C1->A1/A2, C2->A1/A2 [equivalence]) presented 10 times in a quasi random order, again with the position of comparisons counterbalanced across trials (see Figure 2).

In Experiment 1 reported by Cullinan et al. (1998), five subjects were trained to criterion using the pREP. They were trained to press the space bar when presented with the four tasks A1->B1, A2->B2, B1->C1, B2->C2, and were trained not to press the space bar when presented with the four tasks A1->B2, A2->B1, B1->C2, B2->C1 (see Figure 2). When subjects had reached the training criterion of 90% correct responding on a block of trials, they were presented with the pREP test. This consisted of eight symmetry tasks and four equivalence tasks. Four of the symmetry tasks (i.e., B1->A1, B2->A2, C1->B1, C2->B2) required subjects to respond by pressing the space-bar. The other four tasks (i.e., B1->A2, B2->A1, C1->B2, C2->B1) required subjects not to press the space-bar during the response interval. Similarly, two of the equivalence tasks (i.e., C1->A1, C2->A2) required subjects to press the space-bar, and the other two equivalence tasks (i.e., C1->A2, C2->A1) required subjects not to press the space-bar during the response interval. If subjects did not reach the test criterion of 8 or more correct responses out of 10 on each test task, they were retrained using the pREP and then reexposed to the pREP test. This retraining and retesting continued until subjects either reached the test criterion or demonstrated a stable, incorrect performance (i.e., the difference between scores on each individual test task, across the two blocks of test trials, was two or less [out of a possible total of 10]). Subjects were then retrained again using the pREP and were presented with a MTS test. This tested for the same relations as the pREP test, but on each trial two comparisons were presented with each sample (e.g., in a symmetry trial B1 might be presented as a sample with A1 and A2 as comparisons). Therefore, the MTS test consisted of 4 symmetry tasks and 2 equivalence tasks (see Figure 2). If subjects did not reach the test criterion on this MTS test they were again retrained (using the pREP) and retested until they either reached the test criterion or demonstrated a stable incorrect performance. Finally, subjects were retrained to criterion and tested using the pREP.

The results were somewhat surprising. The pREP training and testing proved to be very effective in producing symmetry responding, but relatively ineffective in producing equivalence responding. Furthermore, the MTS test appeared to produce equivalence more readily than the pREP. Because the MTS test apparently facilitated equivalence responding, we decided to repeat Experiment 1, but present the MTS test before the pREP test. Would earlier exposure to the MTS test (relative to Experiment 1) facilitate equivalence responding on a subsequent pREP test? The results from the second experiment demonstrated that even when subjects are presented with a MTS test immediately after pREP training, equivalence responding does not readily emerge, although, as in Experiment 1, symmetry responding was universal.

The results of these two experiments, and the two others also reported by Cullinan et al. (1998), demonstrated that although the pREP can produce equivalence responding, it is not very effective in doing so without also exposing subjects to MTS procedures. Across all four experiments, 10 of the 20 subjects demonstrated equivalence responding on pREP tests, whereas 16 of the 20 subjects demonstrated equivalence responding on MTS tests. Furthermore, only one subject demonstrated equivalence responding on a pREP test without prior exposure to MTS training and/or testing.

The results of this original study were also replicated in many subsequent experiments (Cullinan et al., 2000, for details). Regardless of which version of the pREP was used, or the number of training trials required to reach criterion, in general the pREP was as effective as the MTS procedure in producing symmetry. In contrast, however, equivalence responding, although readily demonstrated using the MTS procedure, was not reliably produced by the pREP without providing a particular a history of MTS training and testing.

By the end of our second study (Cullinan et al., 2000), it was clear that the use of MTS could facilitate the emergence of equivalence responding on the pREP. The next aim of our research was to identify possible sources of contextual control that could be incorporated directly into the pREP to produce an effective go/no go equivalence methodology (i.e., without the need for pre-exposure to MTS). This was achieved in the study conducted by Cullinan et al. (2001), in which it was demonstrated that introducing contextual cues for relations of “same” and “different” produced an effective pREP. In fact, two different methodologies were adopted. First, the words “same” and “different” were used as response options on the pREP (instead of "press" and "no press" responses on the space-bar). In effect, subjects were required to press a key marked with the word "Same" on CS-positive/Sd trials, and to press a key marked with the word "Different" on CS-negative/Sd trials. Second, multiple exemplars of non-arbitrary pretraining (see Dymond & Barnes, 1995, 1996; Roche & Barnes, 1996; Steele & Hayes, 1991) were used to attach the functions of “same” and “different” to arbitrary response options, which were then used in subsequent pREP training and testing. That is, subjects were first trained, across a number of exemplars, to choose one arbitrary stimulus in the presence of identical stimuli (thereby establishing a "same" function for the arbitrary stimulus) and to choose a second arbitrary stimulus in the presence of physically different stimuli (thereby establishing a "different" function for the second arbitrary stimulus). Once the "same" and "different" functions had been established for the two arbitrary stimuli, two response keys were assigned to these stimuli for subsequent training and testing using the pREP (i.e., subjects pressed the "same" function key on CS-positive/Sd trials, and pressed the "different" function key on CS-negative/Sd trials). As indicated above, using the words "same" and "different," or pretraining "same" and "different" functions, proved to be highly effective in generating both symmetry and equivalence relations on the pREP. In fact, 12 out of 12 subjects demonstrated equivalence class formation using these procedures. Somewhat unexpectedly, however, when the words “Yes” and “No” or the phrases “Goes with” and “Does not go with” were used as response options, the pREP once again produced reliable symmetry responding but failed (except in one case out of 8) to produce the predicted equivalence relations. These data indicated, therefore, that quite specific relational cues (*same* and *different*) were required in order to establish the pREP as a reliable method for producing equivalence class formation in verbally sophisticated adult participants. Before considering how RFT might account for these results, let us now briefly consider two of the main ways in which the data from our work with the pREP relates to previous research in the area of stimulus equivalence.

Dissociation of symmetry and equivalence. The finding that the pREP readily produces symmetry, but rarely produces equivalence responding, may have important conceptual implications. Early accounts of equivalence (e.g., Carrigan & Sidman 1992; Sidman, 1990) conceptualized it as a unitary phenomenon, but more recent research, as well as the current findings, suggests that this conceptualization may be inadequate. In fact, results arising from the pREP suggest that symmetry and equivalence do not necessarily function as whole or complete behavioral units. These data are consistent with the work of Pilgrim and Galizio, (1990, 1995) who used baseline reversal procedures to examine equivalence responding in adult subjects. They first trained a series of conditional discriminations, following which subjects demonstrated symmetry and transitivity/equivalence responding. They then trained the reversed baseline conditional discriminations and found that subjects' performances on these were readily sensitive to the changed reinforcement contingencies. When they subsequently tested for symmetry and transitivity/equivalence relations based on the reversed discriminations, they found that symmetry responding was sensitive to the changed reinforcement contingencies, but transitivity/equivalence responding was not. That is, subjects consistently responded to symmetry probes in accordance with the reversed baseline relations, but responded to transitivity/equivalence probes in accordance with the original conditional discriminations. This finding is also consistent with results of other research with adult subjects that shows that equivalence responding is resistant to change based on the manipulation of the baseline relations (e.g., Saunders, Saunders, Kirby, & Spradlin, 1988).

Similarly, Roche, Barnes, and Smeets (1997) used a stimulus pairing procedure whereby either sexual film clips or non-sexual film clips were paired with nonsense syllables. This procedure was employed along with MTS training and testing procedures to examine the effects of incongruous stimulus pairing and/or matching, on equivalence test performances. Roche et al. (1997, Experiment 3) found that once combined symmetry and transitivity had been demonstrated on a MTS procedure, it was highly resistant to change even after repeated exposures to incongruous contingencies. However, they reported (Experiment 3, Condition 1) that symmetry relations were sensitive to changed contingencies even when combined symmetry and transitivity relations based on the same conditional discriminations were not.

The findings of the current program of research further support the argument that the relational responses illustrative of stimulus equivalence, are flexible, separable behaviors that may be under the control of specific environmental variables (but see Saunders, Drake, & Spradlin, 1999). Indeed, further work with the pREP, and perhaps other procedures, may help to identify the key variables involved in producing various patterns of derived relational responding, including those instances in which the component relational operants of symmetry and equivalence either separate or combine (Healy, Barnes-Holmes, & Smeets, 2000; Smeets, Barnes-Holmes, Akpinar, & Barnes-Holmes, 2003; Wilson & Hayes, 1996).

The pREP as a context for stimulus compounding. One of the conclusions we drew during our research is that the pREP may serve as a context for stimulus compounding. This conclusion was derived, in part, from the results of a study reported by Wulfert, Dougher, and Greenway (1991). These researchers used a think aloud procedure and protocol analysis to monitor the verbalizations of adult subjects during equivalence training and testing. The main finding of the study was that subjects who passed the equivalence test often described the relations among stimuli (e.g., "Circle goes with open triangle"), whereas those subjects who failed often described sample and comparison stimuli as unitary compounds (e.g., "Together they look like a house"). The most interesting feature of this research in the current context is that most of the latter subjects (who described compounds) produced high levels of symmetry but little or no equivalence responding, whereas most of the former subjects (who described relations) produced both symmetry and equivalence. Based on these earlier data, we suspect the pREP provides a context for subjects to respond to pairs of stimuli as unitary compounds, and thus it readily produces symmetry but not equivalence responding. However, when appropriate relational cues (e.g., "same" and "different") are introduced into the pREP, both symmetry and equivalence readily emerge. Of course, even if our suspicion turns out to be correct, and the pREP does in fact generate stimulus compounding, we will still need to explain why this procedure has this particular effect (the subsequent section on RFT provides one possible explanation). In any case, the pREP data may be seen as providing additional evidence to support the earlier work of Wulfert et al. (1991) on the importance of relational terms in establishing equivalence classes. Interestingly, this focus on the role of relational terms is consistent with the RFT explanation for equivalence class formation, and thus the pREP data may be usefully interpreted from this theoretical perspective. Before closing, therefore, we will consider how RFT might account for the main findings arising from the pREP studies.

Relational Frame Theory: An interpretation of the pREP. As outlined earlier, according to RFT there may be contextual cues for equivalence responding present in the MTS procedure itself (i.e., most adult subjects will likely have educational histories with MTS-type tasks that are discriminative for matching things, words, or objects that are deemed to be from the same semantic categories). For the pREP, however, the presence of such a history seems unlikely, in that children are not usually taught to match semantically equivalent pictures, words, and objects using go/no-go procedures. Thus the structure or format of the pREP is unlikely to function as a contextual cue for the equivalence responding that is typically observed on MTS.

Given this lack of contextual control on the pREP, the test trials for combinatorial entailment may be rendered somewhat ambiguous (see also Dube & McIlvane, 1996; McIlvane, Serna, Dube, & Stromer, 2000).

Consider, for example, the test trial C1->A1 presented in the Cullinan et al. (1998) study. The training history of A1->B1->PRESS and B1->C1->PRESS should generate C1->A1->PRESS if a contextual cue has established PRESS as an equivalence response (i.e., PRESS is functionally equivalent to picking the correct comparison on MTS). However, the training history of A1->B2->NO PRESS, and B2->C1->NO PRESS should generate C1->A1->NO PRESS if a contextual cue has established NO PRESS as an equivalence response. Because the pREP apparently fails to establish contextual control for the PRESS and NO PRESS responses for specific relational frames, tests for combinatorial entailment are rendered relationally ambiguous, and thus the lack of equivalence responding on the pREP is consistent with RFT. In addition, RFT predicts that a history of MTS training and testing, which may provide a context for equivalence relations, or using the relational terms "same" and "different" (or providing functionally similar pretraining), should increase the likelihood of equivalence responding on the pREP. As described previously, this is exactly what Cullinan et al. reported across their three studies.

Although the foregoing RFT interpretation may seem plausible, it remains incomplete. If there was lack of contextual control over the PRESS and NO PRESS responses for specific relational frames, then why did subjects continue to fail the equivalence tests when “more specific” response options were incorporated into the pREP (i.e., “Yes” and “No”, and “Goes with” and “Does not go with”)? Furthermore, assuming that lack of contextual control was the main problem, why did so many subjects consistently demonstrate symmetry responding, which according to RFT must be under some form of contextual control? These two questions are interrelated and thus we will address both simultaneously.

The response options “Yes,” “Goes with,” and so forth, do not indicate the specific class of relational frame involved. For example, given a contextual cue for “Different” a circle would *go with* a square, but given a cue for “Same” the circle would go with another circle. The critical point here is that the lack of relational specificity inherent in words and terms such as “Yes” and “Goes with,” may provide reliable control over symmetry or mutual entailment, but not over combinatorial entailment. Imagine you are told “A goes with B” and “B goes with C”. There are at least three generic relational cues -SAME, DIFFERENT, and OPPOSITE- that would control the mutually entailed relations, B goes with A, and C goes with B (e.g., if A is the same as, opposite to, or different from B, then B is the same as, opposite to, or different from A, respectively). In contrast, only the SAME cue would control the combinatorially entailed relation, C goes with A. That is, if A is the same B and B is the same as C, then C and A are the same; however, if A is opposite to B and B is opposite to C, then C and A are the same, not opposite; if A is different to B and B is different to C, the relation between C and A remains unknown –C and A could be the same or different. In effect, relational terms that do not specify a particular relational dimension create greater relational ambiguity at the level of combinatorial entailment, relative to mutual entailment. Naturally, high levels of relational ambiguity would undermine the type of relational control that the researcher is seeking to establish in the experimental context. Insofar as the response options "Yes" and "Goes with" created this type of relational ambiguity, high levels of failure on the C-A tests using the pREP are to be expected. On balance, one could argue that non-specific relational terms might also produce some ambiguity at the level of mutual entailment because some frames, such as comparison, are not symmetrical (if A is more than B, B is not more than A). Insofar as this is the case, how does RFT account for the fact that symmetry was demonstrated so consistently on the pREP, but equivalence was not?

One possible explanation is that the symmetry responding constituted arbitrarily applicable relational responding under the control of the non-arbitrary or formal stimulus properties of the symmetrically related stimulus pairs (e.g., compounding). For example, when a subject was trained to press the space bar (or press the "Yes" or "Goes with" key) when presented with ROG and BEH, these two stimuli might have become compounded based on some non-arbitrarily applicable property (e.g., the first letter of ROG and the first letter of BEH are physically similar). As indicated earlier, using the "think of two nouns" exercise, RFT argues that this type of contextual control by non-arbitrary properties is quite common in the natural environment. Thus, when contextual cues for the highly arbitrary type of relational framing known as stimulus equivalence are not present in an experimental context, control by non-arbitrary cues, such as stimulus compounding, is more likely to emerge. This RFT interpretation is entirely consistent with the apparent compounding effects observed with the pREP.

Of course, the foregoing RFT interpretation of the pREP studies is somewhat post-hoc and rather speculative. Nonetheless, the theory can readily accommodate the data, and moreover engaging in this type of RFT-interpretative exercise serves to highlight possible sources of behavioral control that reside both inside and outside the experimental environment. In particular, RFT focuses on the likely verbal or relational functions that specific features of the procedure might have for the participants, and how these functions might help explain the observed performances. Furthermore, it is worth noting that our use of specific relational terms, and the functionally equivalent pretraining, to generate reliable equivalence class formation with the pREP was guided by RFT.

Conclusion

The original aim of the empirical work reported in the latter half of the current article was to extend the number of available procedures for examining stimulus equivalence, and derived relations more generally, in an effort to broaden the scope and range of experimentation in this area. However, the program of research, which started with an almost exclusively procedural focus, has contributed towards the more theoretical concerns surrounding the study of derived relations. We do admit that the empirical work, as it stands, does not allow us to draw any definitive conclusions about the adequacy of RFT as a modern behavioral theory of human language and cognition. Nevertheless, exploring different methodologies for studying derived relations allowed us to “test” the theory by determining if it can be readily used to interpret the results that arose from those novel procedures. Furthermore, the development of the respondent-type training procedure and the pREP has also given rise to other novel methodologies that are being used to explore the implications of RFT as an account of human language and cognition (see also Barnes, et al., 2000; O’Hora, et al., in press; Stewart, et al., in press). We anticipate that further work along similar lines, in which theory and methodology walk hand-in-hand, will serve to invigorate a modern and progressive behavioral research program in human psychology.

[2] Consistent with our previous publications in this area, we have included the suffix "type" to indicate that the respondent training procedure described in this article differs considerably from traditional respondent conditioning experiments. In our procedure, for example, no unconditional stimuli are presented, and we do not measure responses that are closely related to the activity of the autonomic nervous system. We should also stress, that using the term respondent-type training does not imply that the main behavioral process produced by this procedure is best characterized as respondent behavior (see subsequent material on the theoretical interpretation of the respondent-type data).

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