Perspect Behav Sci (2018) 41:9–32
https://doi.org/10.1007/s40614-018-0154-9

EDITORIAL

Editorial: What Sidman Did – Historical and Contemporary Significance of Research on Derived Stimulus Relations

Thomas S. Critchfield[1] · **Dermot Barnes-Holmes**[2] · **Michael J. Dougher**[3]

Published online: 30 April 2018

> The problem of equality (or of *equivalents*, as it has been called) is precisely the problem of finding alternative stimulus configurations for which some attribute of a response remains invariant. This problem shows up in many forms and in many fields of inquiry. As a matter of fact, an inventory would probably show it to be one of the commonest problems tackled by psychologists. (Stevens, 1951, p. 36)

It is 1920s America, and an obscure reaction time experiment (Rexroad, 1926) is underway. A man sits before a light that periodically flashes in one of four colors. The

Author Note

The literature of derived stimulus relations is dense with technical details that tend to scare off readers. The present essay is an attempt to explain the importance of this literature without becoming too entangled in the technical details. We are grateful to Dan Fienup for helpful comments on a draft of the essay and to all of the accomplished scholars who contributed to the present journal issue. Authors of the present essay may be contacted via electronic mail: Barnes-Holmes: dermot.barnes-holmes@ughent.be; Critchfield: tscritc@ilstu.edu; Dougher: dougher@unm.edu.

✉ Thomas S. Critchfield
tscritc@ilstu.edu

Dermot Barnes-Holmes
dermot.barnes-holmes@ughent.be

Michael J. Dougher
dougher@unm.edu

1 Illinois State University, Normal, IL, USA

2 University of Ghent, Ghent, Belgium

3 University of New Mexico, Albuquerque, NM, USA

man is told to move his middle finger as quickly as possible when the light flashes green. With practice, he reliably moves the finger when he sees the green light but never otherwise. Then, on a few surprise occasions, the printed word “green” is presented instead of a light, and *the man flexes his finger*. Intuitively this seems unsurprising; after all, the subject is a typically developing member of a highly verbal species. But our intuition dodges a critical question: *Why*, within the scope of behavior principles as we understand them, does this man do what he does?

The Rexroad (1926) experiment is largely forgotten[1] but the question it evokes helps to frame one of the most vexing problems in the history of Psychology. Here the stimuli (word and light) are hardly confusable. They have nothing physically in common, with one being a colored light and the other being a configuration of squiggles on a white surface. There is no reason to think that the subject’s species (*Homo sapiens*) has been biologically programmed to respond to them in the same way, but nevertheless he does. As Hull (1939) observed, “How can we account for the fact that a stimulus will sometimes evoke a reaction to which it has never been conditioned?” (p. 9). *Something* clearly connects the dissimilar stimuli, and the nature of this connection, which may be referred to as a *stimulus relation*, is one of the Holy Grails of psychological inquiry.

Fast forward nearly half a century to a laboratory on the campus of a developmental center outside of Boston. Murray Sidman and his colleagues are attempting to teaching basic reading skills to an individual with severe intellectual disabilities. The researchers are not thinking about Psychology’s Big Questions (e.g., see Sidman, 1995), only about the task at hand, but this does not dull their excitement when a breakthrough is made. In *Equivalence Relations and Behavior: A Research Story*, Sidman (1994) recalled a critical moment of the investigation:

> Our subject in this experiment was a severely retarded boy with whom we had been working for several years in the context of an intensive teaching project at the Walter E. Fernald State School. . . We had taught him step by step – agonizingly slowly – to dress himself, to feed himself, to make his bed, to help with chores, to draw simple figures with pencil and crayon, to name pictures, objects, and features of objects like colors, sizes, and quantities, and to speak some of his needs instead of using violence to draw our attention. We had not yet been able to teach him to read with comprehension. In the experiment, it took us more than 15 hours of instruction over a four week period to teach him to match 20 spoken to printed three-letter words. And then, at the end of that month, we watched him suddenly matching the 20 printed words to pictures and vice versa without having been directly taught to do so.
>
> During the final test session, the excitement in the laboratory was palpable. We were all outside the experimental cubicle, jumping up and down with glee as we watched correct choice after correct choice registering on the recorder. My son, who was helping in the lab that summer, said to me, “Dad, I never saw you lose your cool like that before.” Looking inside the cubicle through a one-way mirror, we could see Os Cresson, good lab technician that he was, sitting quietly behind the subject, hands folded in his lap, not moving – hardly breathing, saying nothing, only his eyes, wide

[1] According to a Google Scholar search conducted February 2, 2018, it has been cited 12 times in 92 years.

> open and unblinking, betraying his tension. But when the boy had completed the tests, Os could contain himself no longer. He grabbed the … boy in a bear hug and cried out, “Goddammit, Kent, you can read!” (p. 34).

The published study that emerged from this work (Sidman, 1971), like the Rexroad (1926) experiment before it, was largely ignored – at least at first. In the first several years after its publication, it was cited only a handful of times, mostly in publications focusing on practical aspects of teaching persons with developmental disabilities. Ultimately, however, that report has come to be seen as a major landmark in the experimental analysis of human behavior generally, and in the analysis of language and cognition specifically. Sidman and colleagues, it turned out, had begun to devise a means of addressing problems that had occupied psychologists and other scholars for more than 150 years. Below we briefly summarize some of the advances that owe a debt to Sidman’s pioneering work.

The Concept of Stimulus Relations

The phenomenon that Sidman identified and explored with his collaborators across several decades came to be called *stimulus equivalence*. This term was co-opted from earlier scholars (e.g., Hull, 1939; Kluver, 1933; Lashley, 1942; Smith, 1936; Tolman, 1938), and as employed by behavior scientists it has a precise technical definition on which we need not dwell for present purposes. To capture something of the core idea, however, one might invoke notions such as *concepts* and *categories* (Zentall, Galizio, & Critchfield, 2002). Keller and Schoenfeld (1950) did precisely that when they wrote that, “when a group of objects gets the same response, when they form a class the members of which are reacted to similarly, we speak of a concept” (p. 160). Let us follow their lead and say loosely that stimulus equivalence involves dissimilar stimuli being responded to in the same way.

This is enough to introduce the idea of a *stimulus relation*. Stimuli are “related,” or form a “class,” in the sense that responding to any one of them can be understood fully only by knowing what responding the others evoke. For instance, we can infer that a green light “is related to”[2] the printed word “green” when Rexroad’s (1926) subject moves his finger in the presence of them both. There are, however, many kinds of stimulus relations (e.g., Hayes, Barnes-Holmes, & Roche, 2001), of which equivalence is only one.

> The word “relation” is used to designate several kinds of connection between separable elements. It refers to (a) physical associations, for example, between two or more stimulus objects differing in a single dimension such as size, brightness, or position; (b) conceptual associations such as the associations between synonyms, between antonyms, between object and attribute…; and (c) connections resulting from special context such as the relation between “rabbit” and “corn” in the sentence, “The rabbit is eating the corn” …. (Reese, 1968, p. 1)

[2] The English verb *to relate* originates from the Latin *referre*, which means “to carry back.” This definition is consistent with the use of *relation* in Psychology, in that one stimulus may be said to “carry back” or acquire some of the function of another stimulus to which it is related. As we will illustrate later, however, this “carrying back” can become complicated and is not always a simple matter of functional mimicry.

Since even before Psychology coalesced as a discipline (Locke, 1690/1997; Mill, 1829/1869), scholars have struggled to understand what, exactly, constitutes a stimulus relation at the level of psychological process (see also Brown, 1860; James, 1890/1950; Mach, 1886/1914; McCosh, 1886; Spencer, 1883). To the casual reader this may sound like idle philosophical debate but its resolution has pivotal implications for how to study stimulus relations and how to engineer them for practical benefit.

To many observers it has seemed obvious that because “similarity” (or any other form of “connection” between stimuli) is not inherent in the physical properties of stimuli themselves, it must trace instead to something taking place in the behaving organism that forges, or *mediates*, the relationship between them. Two camps have entertained different hypotheses about the organismic variables responsible for mediation.[3]

One camp has looked for mediation in the neural underpinnings of perception. Scientists have long known that the way some stimuli are experienced psychologically differs from how the senses register them (this was, for instance, a trademark observation of Gestalt psychologists like Kohler, 1920[4]). Such a disconnect is conveyed in Dodwell’s (2000) observation that, “logically there is nothing to require that the brain representation of a square share any of the physical or geometric properties of a square” (p. 149). For example, identical twins standing fifty feet apart are understood to be identical, despite the fact that the retinal image of the further one is smaller than that of the nearer one. It is as if some process – referred to historically as stimulus equivalence – exists to convert raw sensory input into a “neural representation” that is different from the original stimulus but effective in guiding responding. When dissimilar stimuli evoke the same response, it is assumed that their “neural representations” are equivalent or at least linked in some way. Lashley (1942) came to view this as perhaps the central problem in perceptual neuroscience, expressing “doubt that any progress will be made toward a genuine understanding of nervous integration until the problem of equivalent nervous connections, as it is more generally terms, of stimulus equivalence, is solved” (p. 304).

A second camp has looked for mediation in cognitive process, specifically in an act of *meaning-making* (Rodgers, 2002, p. 845) by which individuals go “beyond the information given” (from the title of a book by Bruner, 1973) to make connections between dissimilar stimuli. This presumed process of meaning making has gone by many names. Brown (1860) invoked a mental act of *comparison*; others have suggested that individuals *reflect* on how stimuli are related (e.g., Brown, 1860; Dewey, 1933; Morgan, 1903; Wheeler, 1929). McCosh (1886) stated, “We only know individual things by the senses, but we know by *contemplating* them that they have relations” (p. 234, italics added). Regardless of how meaning-making has been labeled, it has been vaguely defined, particularly in terms of its origins. To simplify a complex issue, meaning-making has usually been implied to be volitional, in that learners choose, relatively unfettered by situational contexts, when they will make meaning out of dissimilar stimuli. This calls to mind Skinner’s (e.g., 1953) standard objection to treating internal events as causes. When the origin of interesting behavior (like demonstrating stimulus relations) is placed inside the individual, it is beyond the direct reach of the scientist who seeks to analyze it and the

[3] The informed reader will quickly recognize that speaking of only two stances on mediation creates some strange theoretical bedfellows. We do so in service of brevity.

[4] However, the notion of neural representation as described in this paragraph was antithetical to most Gestaltists, who instead tended to think in terms of direct (unmediated) connections between sensation and perception (e.g., Reese, 1968).

technologist who hopes to harness it for practical good (e.g., Critchfield & Twyman, 2014). Even if mediational processes exist, therefore, they may not be the right launching pad for a systematic analysis of the behavior they mediate.

Given the limitations of meditational accounts, it is significant that Sidman and colleagues chose to focus on measuring the shared behaviors that are occasioned by dissimilar stimuli, and on discovering the environmental conditions by which stimulus relations were forged. For example, in the anecdote about Sidman's (1971) seminal research, critical questions concerned what the participant, Kent, had to *do* to qualify as "reading" and what *experiences* had to be provided so that Kent would respond to printed words and pictures in the same way.

Ironically, scholars – even those committed to meditational accounts – have long acknowledged that stimulus relations are more likely to arise under some circumstances than others (e.g., Hull, 1939; Kluver, 1933). Typically, however, the interest has been on what internal process must be taking place in those circumstances. By focusing on the circumstances themselves, Sidman and colleagues freed the study of stimulus relations from decades of existential hand-wringing over the properties of a hypothesized meditational process. They placed their emphasis squarely on the *experiences* that create stimulus relations: "Instead of assuming that stimulus equivalence required response mediation," Sidman (1995) later wrote, "We asked ourselves, 'Under what conditions do we say things like *urn means vase*, or *the word dog represents a dog*, or *this shopping list tells us what to buy*?" (unpaginated, italics in original). Thus stripped of mediational baggage, "'stimulus equivalence' is not itself a theoretical concept, although it has sometimes been used as if it were. It is a descriptive or shorthand term meaning that the stimuli being tested arouse the same response" (Reese, 1968, p. 12). This emphasis on stimuli and responses is, of course, a style of theorizing (e.g., Skinner, 1950) with which readers of the present journal are quite familiar, and it has had far-reaching implications in the study of stimulus relations, two of which we consider next.

Two Implications of Sidman's Approach

Constructing Versus Deconstructing Stimulus Relations

Historically, much effort has been invested in logically inferring (e.g., Locke, 1690/1997; Brown, 1860) and empirically describing the properties of stimulus relations that already exist. The Rexroad (1926) reaction time study mentioned at the start of this article provides an example, as does a large body of research in cognitive science on what is sometimes referred to as semantic networks (e.g., Collins & Loftus, 1975; Smith, Rips, & Shoben, 1974). The guiding idea in this research is that knowledge consists of bits of information that are represented separately in memory but linked by semantic (meaning-based) connections. A "knowledge network" like that of Figure 1 therefore incorporates the mental representation of many stimuli and ideas that may be related in a variety of ways. Such networks have been hypothesized based on structured interviews and other procedures that map out patterns of shared responding among stimuli or, it may be said, among categories of ideas that in some fashion "belong together." For example, free association might be employed in which participants, given a word, are asked to speak the first

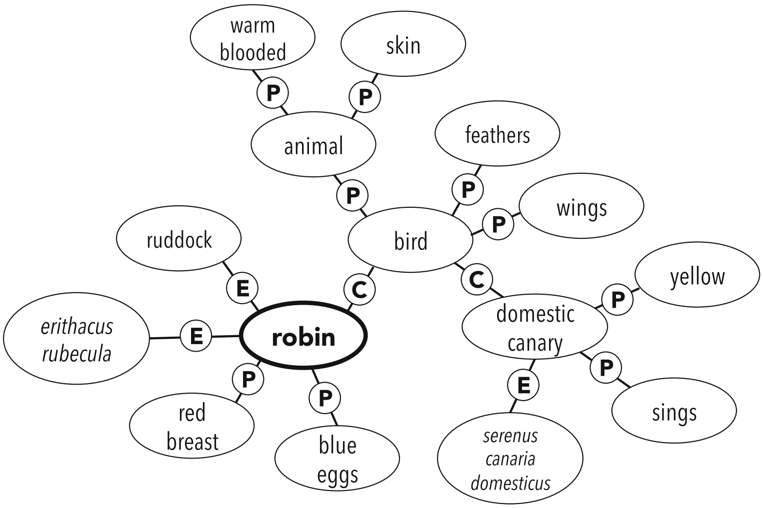

Fig. 1 Example of a hypothesized semantic network consisting of bits of knowledge related, directly or indirectly, to *robin*. For types of relations, E = one thing is equivalent to another; P = one thing is a property of another; and C = one thing is a category that subsumes the other. Adapted from Ashcraft (1994), Figure 6-1

word that comes to mind. Words that evoke each other are taken as signs of close semantic association.

From the perspective of a behavior scientist, the preceding approach consists "of describing terminal performance without examining the necessary conditions for its emergence" and can be expected to "discourage attention to the role of experience in creating and maintaining conceptual behavior" (Zentall et al., 2002, p. 238). By contrast, when coupled with the behavior-science perspective that interesting behavioral phenomena are the product of environmentally-imposed variability (e.g., Sidman, 1960), an emphasis on stimuli and responses leads naturally to programs of research that seek to *construct* stimulus relations, that is, to examine their origins by building them from scratch. In Sidman's seminal work, this approach was forced by working with individuals with intellectual disabilities who likely lacked the well-developed "knowledge networks" of typically developing adults, but the approach was soon extended to basic laboratory research in which the stimuli were chosen expressly because learners were unlikely to have pre-existing repertoires with respect to them (see Sidman, 1994; though for a productive hybrid approach see Fields & Arntzen, this issue). The result was a research program with a distinctly how-to feel, one that has begun to fuel a considerable technology for *creating* "knowledge" (Brodsky & Fienup, this issue; Critchfield & Twyman, 2014; Rehfeldt, 2011).

Derived Stimulus Relations: Lawful Origins of Emergent Learning

Applied technology harnessing stimulus relations especially emphasizes those aspects of learning that have been characterized as creative or generative. Perhaps all teachers assume that their students will one day derive unique wisdom from what they have been taught, and scholars have often assumed that learners possess the capacity to do so. This was Bruner's (1973) emphasis in an influential early treatise of cognitive psychology called *Beyond the information given: studies in the psychology of knowing*. The Gestaltists (e.g., Kohler, 1920) referred to this active process of "going beyond" as "insight," and Dewey (1933) believed that it occurred when learners engage in "reflective thinking" that reveals previously unrecognized connections between ideas. Even Aristotle (in *De Anima*) asserted that mental abilities extend beyond what experience has directly taught.

Importantly, when "going beyond" occurs, the result is "free" learning that does not trace in a linear fashion to what experience directly taught. Dewey (1933) offered as example the following syllogism. A student who is taught that *All humans are mortal* and then that *Socrates is human* should be able to derive, without further instruction (but, presumably, after some reflective thinking), that *Socrates is mortal*. This is "free" learning because two facts were taught, but three were mastered, upending the traditional notion that the ceiling for learning outcomes is 100% mastery of what is taught.

Also importantly, in traditional accounts the mechanisms by which learners go "beyond the information given" have remained somewhat obscure, perhaps because of an emphasis on cognitive meditation. These accounts imply that "free" learning can be expected only when the learner *chooses* to "think insightfully" or to engage in "reflective thinking." As noted earlier, if this is all that is involved, then "free" learning is neither possible to study systematically (scientists cannot control the relevant variables) nor to promote it through judicious instruction (teachers cannot control the relevant variables).

From very early on, research by Sidman and colleagues tackled the problem of "free" learning head on. Figure 2 (left side) summarizes key aspects of the Sidman (1971) experiment. The learner, Kent, was already able to pick out a picture of a cat when another person said "Cat" (presumably he had learned to do this prior to the experiment). He was taught to pick out the printed word CAT under the same circumstance. Subsequently, when shown the printed word he knew to pick out CAT. In essence, the stimuli became interchangeable.

One way to describe this interchangeability is to say that, once an integrated class of stimulus relations forms, the behavioral functions served by any one stimulus influence,

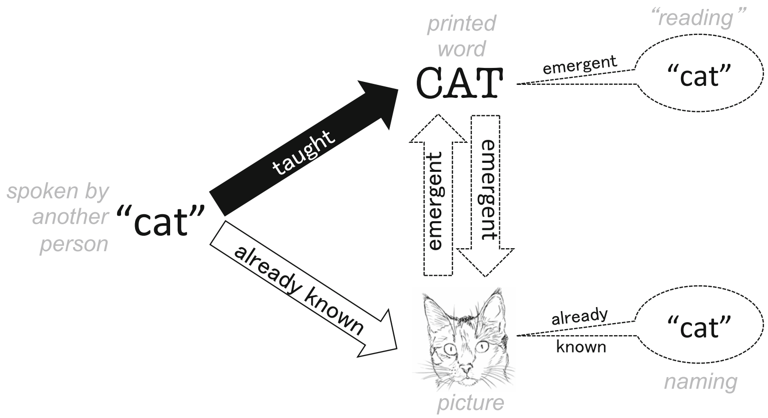

Fig. 2 Summary of the procedure employed to develop skills related to reading in Sidman (1971). Left side: Arrows run from stimulus presented to stimulus chosen in response. Right side: Subject's speaking repertoire. See text for further explanation

or *transform*, the functions served by others (Dymond & Rehfeldt, 2000). Thus, Kent began to respond to a printed word as he would to a picture or to the sound of the same word being spoken. Further evidence of this is shown in Figure 2 (right side), which shows that prior to the Sidman (1971) experiment Kent was already able to say "Cat" when shown a picture of a cat. Once the cat picture and the printed word CAT became related, albeit indirectly, he spontaneously responded to the printed word as he would to the picture (by saying "Cat").

Sidman (e.g., 1995) was aware of precedents for such effects, which Hull (1939) had labeled *mediated generalization*. For present purposes *generalization* can imply what it normally does, the transfer of prior learning to a new situation, and *mediated* can be thought of, not necessarily in terms of the cognitive or neural mediation of traditional theories, but rather simply as prior learning making generalization possible (Cofer & Foley, 1942). Sidman also knew that the existing research on mediated generalization had not reaped many dividends, perhaps because of its association with models like Hull's that were top-heavy with hypothetical constructs. By focusing attention squarely on behavior, Sidman and colleagues gradually mapped out some of the conditions that create "free" learning, which has come to be called *emergent learning* or, more commonly, an expression of *derived stimulus relations*, with both labels acknowledging the debt that new abilities owe to prior experience. In Figure 2 (left side), for example, Kent's ability to say "Cat" when shown the printed word was a derived stimulus relation, and was possible because of two previously-learned abilities.

In Sidman's (e.g., 1994) view it is impossible to talk about stimulus equivalence without acknowledging both experience-imposed and derived stimulus relations. Table 1 shows a partial example for a stimulus equivalence class involving 3 stimuli.[5] This is a more sophisticated and inclusive formulation than found in earlier ideas about stimulus relations, which could focus on the "interchangeability" of as few as two stimuli and, because of their focus on pre-existing equivalences, could not always distinguish between experience-imposed and derived relations.

Sidman (e.g., 1994, 2000) also came to believe that derived stimulus relations are not simply *possible* because of (derived from) certain prerequisite experiences; they are a *necessary* outcome of those experiences. As Sidman (1995) explained, "The formation of equivalence relations is one of the functions of reinforcement, with what used to be called *mediating responses*, simply joining discriminative stimuli, conditional stimuli, and reinforcing stimuli as members of the equivalence class that reinforcement establishes" (unpaginated, italics in original). In other words, Sidman viewed derived stimulus relations as elementals, as inherent in the reinforcement process (at least for humans; see below). Among other things, this has profound implications for applied technologies that must assure reliably beneficial outcomes and seek to do so efficiently by harnessing derived relations. Derived stimulus relations follow "natural laws" of emergence that can be set into motion through skilled planning of interventions (e.g., Critchfield & Twyman, 2014).

[5] The smallest possible equivalence class; note that as the number of stimuli in a class increases the ratio of derived to experience-imposed relations increases (e.g., Lane & Critchfield, 1998).

Table 1 Stimulus relations, directly taught and derived, for an illustrative small stimulus class involving the stimuli labeled as A, B, and C

Stimuli	Taught	Derived
A, B	Upon encountering A, respond as if encountering B	Upon encountering B, respond as if encountering A
A, B	Upon encountering A, respond as if encountering C	Upon encountering B, respond as if encountering A
B, C		Upon encountering B, respond as if encountering C
		Upon encountering C, respond as if encountering B

Interesting Developments

Integration of Stimulus Relations with Other Behavior Principles

An account of stimulus relations rendered in the style of behavior theory is, of course, inherently compatible with existing aspects of behavior theory. One form of potential synergy involves examining stimulus relations through the lens of other behavior principles – as, for example, when the formation of stimulus relations is considered in light of concurrent reinforcement contingencies (McIlvane & Dube, 2003) or behavioral momentum theory (Belisle & Dixon, in press). A second form of potential synergy consists of drawing upon stimulus relations research to broaden our perspective on other behavioral principles. For example, several studies have shown that neutral stimuli can acquire reinforcing and punishing functions through indirect association with stimuli that already function in this way (e.g., Hayes et al. 2001). Not only that, but when participating in “frames of opposition” (in which the relation of interest is “opposite”), a neutral stimulus can acquire aversive functions via indirect association with appetitive stimuli (Whelan & Barnes-Holmes, 2004, described further below). Such findings force a re-thinking of the classical behavior science position that conditioned reinforcers and punishers owe their function to direct pairing with already-effective consequences (e.g., Kelleher & Gollub, 1962).

The ultimate goal is a complete integration of stimulus relations concepts into the canon of behavior principles, and there have been interesting developments in this regard. For example, Davison and Nevin (1999) proposed a quantitative model in which stimuli, responses, and reinforcers have equivalent functions. Although their model did not specifically reference stimulus equivalence and other instances of derived stimulus relations, it accounts for important findings regarding conditional discrimination, which Sidman (1986) and others have considered one of the building blocks of stimulus-relation formation. Sidman (2000) made the connection explicit by proposing that reinforcement contingencies render stimuli, responses, and reinforcers equivalent in important ways and therefore incorporate all of these elements into equivalence classes. Papers like Davison and Nevin (1999) and Sidman (2000) can be interpreted as addressing the very foundations of behavior theory and should be regarded as required reading for anyone seeking a thorough understanding how stimulus relations fit into it.

Non-Equivalence Relations

A theoretical system called Relational Frame Theory (RFT; Hayes et al., 2001) has become a major driver of contemporary research on derived stimulus relations. One reason why is that RFT systematically enumerates the varied types of relations, including but not limited to equivalence, that can exist, thereby providing a framework for understanding instances in which stimuli are related in ways other than interchangeability (Ming & Stewart, 2017). Below we mention two ways in which non-equivalence relations can be important.

First, non-equivalence relations can serve as one of the behavioral functions that propagate through stimulus classes. Figure 3 shows an example based on a study on teaching children with autism to mand. In the left panel, the children first are taught to use a symbol card to mand “more” and “less.” The task is to come up with exactly six objects, so by presenting a particular card the child can ask for more shapes to be added (there is also a “less” card). If the symbol on the card is part of an equivalence class (middle panel), then the other stimuli to which it is related should also, through transformation of function, come to function as a symbol for manding “more.” This is true even for a symbol, like the lightning bolt (right panel), that has never been directly paired with the original mand symbol. The basic idea is that, much like the words “add” or “increase,” the new symbols now function as synonyms for “more.”

Second, non-equivalence relations can serve, not as the behavioral function of interest, but rather as a mechanism for transforming behavioral function. Figure 4 shows an example based on a laboratory study by Whelan and Barnes-Holmes (2004). To ease into a complex design, consider the top, left panel in which a stimulus is made part of an equivalence class. Here the stimulus designated as A is made “the same” with those designated as B and C. As a result, we expect B and C, which have not been directly paired, to become emergently equivalent. Next, in the top, right panel, the same stimulus is made part of a class of opposites. Note here that although the directly-taught relations are of opposition, the derived relation is, in the manner of “the enemy of my enemy is my friend,” one of equivalence. Now consider the middle panel

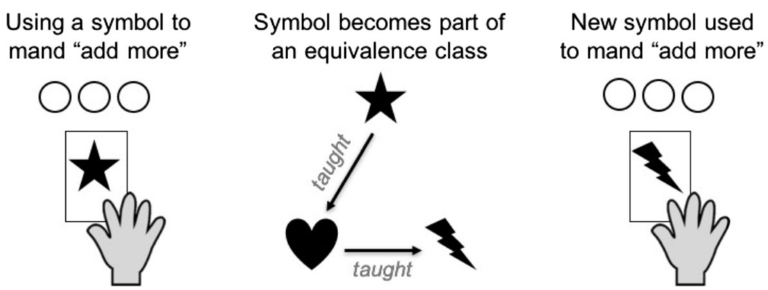

Fig. 3 Emergent manding established through transformation of function. Left: A child is asked to add or subtract items to make exactly six items, and learns to use a symbol to request that more items be added. Middle: The child is taught relations between two pairs of stimuli, resulting in the mand symbol becoming part of an equivalence class. Right: Without any further training, the other symbols in the equivalence class are now used to mand “more.” Based on Murphy and Barnes-Holmes (2009)

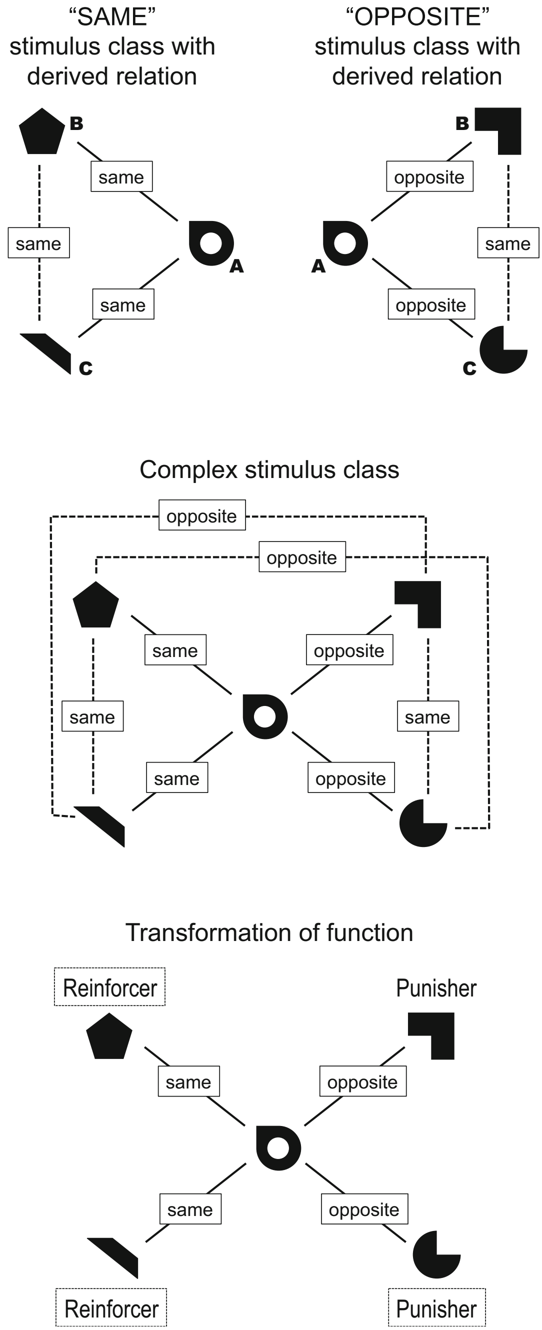

Fig. 4 A complex stimulus class and transformation of function involving nonequivalence relations. Top: Formation of equivalence (left) and nonequivalence (right) relations. Middle: All of those relations combined into one stimulus class. Bottom: Transformation of function based on one of the stimuli having a punishing function. Throughout, solid lines between stimuli indicate directly-taught relations; dashed lines indicate derived (emergent) ones. Based on Whelan and Barnes-Holmes (2004)

of Figure 4, which approximates the actual, more complex stimulus class[6] that was created from a combination of same and opposite relations. Finally, imagine that one of the stimuli in this class is an effective punisher (bottom panel). This behavioral function propagates through the class, but as appropriate to various combinations of same and opposite relations, stimuli never directly paired with the punisher become either "conditioned" punishers *or* "conditioned" reinforcers. This illustrates that the propagation of behavior functions can have many nuances that depend on the types of stimulus relations that are involved.[7]

Relating as a Generalized Operant Repertoire

RFT also takes issue with Sidman's notion that derived stimulus relations are an elemental property of the reinforcement process. RFT asserts instead that the ability to form a given type of relation is at first a directly-reinforced operant, but given experience with multiple exemplars becomes a generalized repertoire, much in the way that imitation has been shown to (Baer & Sherman, 1964). Some evidence supports this proposition (e.g., Luciano, Gomez Becerra, & Rodrigue-Valverde, 2007).

Applications

A successful basic science can have profound implications for understanding the world outside the laboratory (e.g., Dixon & Rehfeldt, this issue), but those implications must be intentionally explored (Mace & Critchfield, 2010). As should be evident from the Sidman (1971) study, derived stimulus relations work was, from the outset, focused on practical problems. Although scientific translation is often conceived as a process of developing applied insights from basic research (Kyonka & Subramamian, in press), in the case of stimulus relations a complex bidirectional flow of ideas has always existed. Resulting from this flow is a rapidly growing literature examining socially important behavior.

One approach has been to model important everyday phenomena under controlled laboratory conditions, with the goal of determining what derived stimulus relations might be implicated. For example, Dougher, Augustson, Markham, Greenway, and Wulfert (1994) focused on transformation of function to examine how clinically-relevant acquired fear responses, and extinction thereof, might propagate through stimulus classes. Using classical conditioning, one stimulus in an equivalence class was made a conditioned stimulus for fear. Without any further intervention, all stimuli in the class, including those never directly paired with the CS, also acquired fear-eliciting properties. When conditioned fear to one stimulus was extinguished, fear-elicitation by all stimuli weakened. This study illustrated how acquired fears of clinical relevance could expand beyond what experience directly creates, and has implications for the implementation of extinction-based therapies. The role of derived stimulus relations in problems of fear and anxiety continues to be a topic of productive investigation (Dymond, Schlund, Roche, & Whelan, 2014; Dymond et al., this

[6] There are many other examples of how stimulus classes can be quite complex (e.g., Augustson et al., 2000; Dougher et al., 2002; Griffee et al., 2002; Sidman, 1986).

[7] This is why we say the behavior functions *transform* instead of the more colloquial *transfer*, which implies derived functions that are identical to the original.

issue). Similar laboratory models have provided insights into such varied phenomena as false memory (Guinther & Dougher, 2010, 2014), analogical reasoning (Stewart, Barnes-Holmes, Roche, & Smeets, 2002), consumer preferences for commercial products (Barnes-Holmes, Keane, Barnes-Holmes, & Smeets, 2000), and social stereotyping (Dixon, Rehfeldt, Zlomke, & Robinson, 2006; Watt, Keenan, Barnes, & Cairns, 1991)

Derived stimulus relations have also been at the fore in creating socially significant behavior change in everyday settings. One key domain of intervention has been academic instruction, with the guiding value being that "knowledge is potentially infinite, but the time available for instruction is not" (Critchfield & Twyman, 2014, p. 215). The "free" learning inherent in derived stimulus relations has been harnessed for the benefit of leaners ranging from those with disabilities (McLay, Sutherland, Church, & Tyler-Merrick, 2013) to college students (Brodsky & Fienup, this issue). For example, Figure 5 shows how Zinn, Newland, and Ritchie (2015) established equivalence classes to teach college students concepts in behavioral pharmacology.

Another growing area of intervention is with children with autism and other developmental disorders, who have been taught academic skills, to recognize facial emotions, to ask substantive questions during conversation, and to use primary verbal operants, (e.g., Daar, Negrelli, & Dixon, 2015; Dixon et al. 2017; Guercio, Podolska-Schroeder, & Rehfeldt, 2004; LeBlanc, Miguel, Cummings, Goldsmith, & Carr, 2003; for a review, see McLay et al., 2013). A particularly noteworthy recent development is the creation of the PEAK Relational Training System, an entire language-focused curriculum, with growing evidence of effectiveness (e.g., Dixon et al. 2017), that is based on basic research on stimulus control and derived stimulus relations.

Concepts of stimulus relations are also shedding light on problems in consumer behavior analysis and organizational behavior management. For example, John B. Watson's contention, during his advertising career, that it is the brand, not the product, that matters (DiClemente & Hantula, 2000, 2003) suggests a primacy of derived stimulus relations over direct contingency control in consumer preference, and experimental work demonstrates how transformation of function may help to explain the development of consumer brand

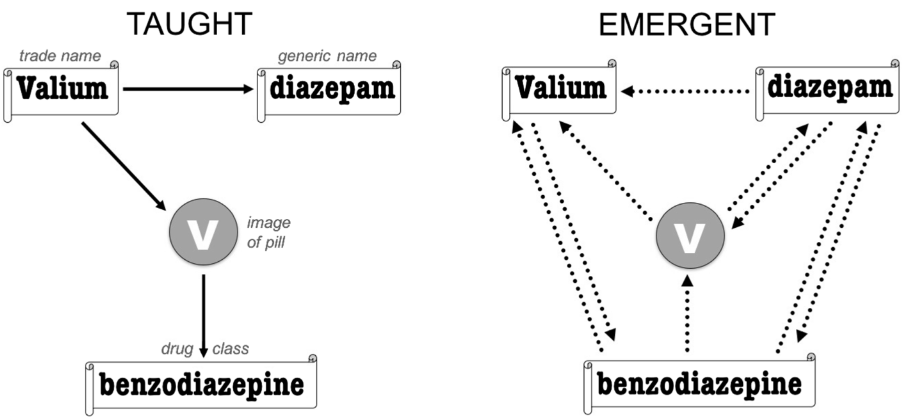

Fig. 5 Using derived stimulus relations to teach drug-behavior facts to college students. Left: Relations that were directly taught, including selecting a drug's generic name when shown its trade name; selecting the correct image of a pill when shown a drug's trade name; and indicating the correct drug class when shown an image of a pill. Right: Derived relations emerging from this procedure. Based on Zinn et al. (2015)

preferences (Barnes-Holmes et al., 2000; see also Arntzen, Fagerstrøm, & Foxall, 2016; Hantula, DiClemente, & Rajala, 2001). Several phenomena of interest in organizational settings, such as motivation, innovation, and worker mental health, have been examined through the perspective of derived stimulus relations, leading to the development of several effective interventions (Bond, Hayes, & Barnes-Holmes, 2006; Hayes, Bunting, Herbst, Bond, & Barnes-Holmes, 2006; Maraccini, Houmanfar, & Szarko, 2016).

Perhaps the most vibrant current area of application is in clinical psychology, specifically through Acceptance and Commitment Therapy (ACT), which has roots in the basic science of derived stimulus relations. For an account of the development of ACT and its relation to RFT, see McEnteggert (this issue). A large body of evidence shows that ACT is effective for problems as diverse as depression (Ameral et al. 2017), anxiety (Avdagic, Morrissey, & Boschen, 2014), and chronic pain (Hann & McCracken, 2014). ACT is not, however, just for traditional clinic-based interventions. It also shows promise in addressing mental health issues in schools (Burckhardt, Manicavasagar, Batterham, Hadzi-Pavlovic, & Shand, 2017; Van der Gucht et al., 2017) and organizational settings (e.g., Bond & Bunce, 2003).

What Makes Us Human

From early in his research program Sidman realized that the study of stimulus relations places behavior science squarely in the context of an age-old quest to define what makes humans unique. Or, in slightly less dramatic terms, Sidman saw stimulus relations as the basis for a theoretical model of the rich repertoire of "symbolic behavior" (e.g., Deacon, 1997) that humans so obviously exhibit. This perspective opens the door to many fascinating lines of inquiry.

Can Nonhumans Do it? Historically, it was assumed that many kinds of animals exhibit stimulus relations (see Reese, 1968), but newer research suggests that a species divide could exist, at least for derived stimulus relations as defined here. In 1982, Sidman and his colleagues published a series of experiments showing that rhesus monkeys and baboons failed to demonstrate a key property of equivalence classes that normally developing young children readily demonstrate (Sidman et al., 1982). Many other researchers have since taken up the question of what aspects of derived stimulus relations may be species-general versus human-specific (e.g., Kastak, Schusterman, & Kastak, 2001; Dugdale & Lowe, 2000; Urcuioli, 2008), and the related question of how stimulus relations may be implicated in the development of verbal abilities that themselves seem uniquely human (Pelaez & Monlux, this issue). To date, no undisputed findings exist to place nonhuman relational repertoires on par with those readily demonstrated by humans, but the matter of "uniquely human" relational repertoires remains a matter of intense debate (Galizio & Bruce, this issue; Hughes & Barnes-Holmes, 2014). For example, computer neural network modeling suggests that derived stimulus relations can exist in nonverbal entities (Ninness et al., this issue). If humans really are "different," this raises the question of what, other than verbal behavior, might make them so.

The Verbal Emphasis of RFT Verbal repertoires have been a primary focus in the development of RFT (Hayes et al., 2001), which addresses verbal behavior in at least three ways. First, derived stimulus relations are considered to be an inherently verbal phenomenon. This is assumed because derived stimulus relations are endemic to normally developing humans; because they arise grudgingly, if at all, in nonhumans; because they tend to first arise coincident with language development (e.g., Pelaez & Monlux, this issue); and because they appear to be implicated in many complex verbal phenomena (e.g., Barnes-Holmes et al., this issue). Second, derived stimulus relations are assumed to be the basis for many sophisticated outcomes with presumably verbal roots, such as the ability to form analogies (Stewart et al., 2002) and contemplate the future (Weil, Hayes, & Capurro, 2011). Third, because RFT assumes a verbal basis for stimulus relations, it is a natural extension to consider how stimulus relations create and interact with rule-governed behavior. This focus helps to establish part of the clinical relevance of derived stimulus relations. This is one way in which RFT provides a backbone for ACT, which views unproductive rule-following as the basis for many human problems and therefore focuses on techniques for dismantling unwanted rule control (McEnteggert, this issue).

Meaning and Complex Thought For more complete examination of the potential of stimulus relations to shed light on complex problems of language and cognition we refer the reader to other sources (e.g., Barnes Holmes et al., this issue; Dymond & Roche, 2013; Hayes et al., 2001; Torneke, 2010; Zettle, Hayes, & Barnes-Holmes, 2016). For present purposes it may be sufficient to revisit Sidman's early perspective on this. He captured the essence of the challenge when he observed that

> . . . terms like meaning, symbolism, and reference make many behavior analysts uneasy because they are usually treated as explanatory concepts, not as behavior that requires explanation itself. (Sidman, 1994, p. 562)

But Sidman realized stimulus relations could help to explain these phenomena. He also realized that such heady topics are matters about which intelligent people are likely to disagree, which he illustrated by reproducing (at the end of *Equivalence rations and behavior: A Research Story)* an exchange of letters between him and Willard Day.

> My own thinking about these terms was greatly clarified by the need to respond to friendly but sharp doubts that Willard Day expressed about my usage of them. I reproduce here some excerpts from our correspondence on these matters – a correspondence that his sudden passing left uncompleted. The discussion illustrates both the sources of a sophisticated thinker's (Day's) unease and the gradual sharpening of my own conception that his unease generated.
>
> It all started when Willard, in a nice note to me. . . also expressed distress about my frequent reference to "meaning." Here is my reply:
>
> October 10, 1986
>
> Dear Willard,
>
> I must confess that I thought my references to "meaning" might get a reaction from you. But you can be sure that when you do react to something I say, I sit up and take notice; your judgment is always meaningful to me. . .

> So here is my problem. I am perfectly at home with Skinner's definition as the determining conditions of verbal behavior, and with his objections to "reference" as an explanation. And yet, it seems to me also true that "meaning" in at least one of its traditional senses – semantic meaning – is based on a real datum. . . The term, "rule-governed behavior," summarizes the observation that with words, you can get people to do things even without their having experienced the relevant contingencies. In this sense, words have meanings; they refer to things, actions, and events. How *do* I handle this observation?
>
> In the simplest case, a word does become equivalent to "the thing it stands for." That is why people call words "symbols." . . . Now I do not regard "symbol" as an explanation for anything, but I do regard it as a name for something real, an observed phenomenon that *requires explanation.*
>
> Is it really wrong to talk about "meaning" in these senses? Should we invent some other term to take its place? I think the equivalence paradigm demonstrates one way that symbols do become established as such, one way that words can come to "mean" what they "stand for." The phenomena are real; we see them all about us and we reproduce them in the laboratory. I think the phenomena are important in their own right, and I think they are also "a special property of language" in the sense that they to make language as powerful as it is (Sidman, 1994, pp. 562–563).

Bridging Old Divides

As Sidman expressed so eloquently to Day, taking stimulus relations seriously means wading into topics that traditionally have been the province of scholars outside of behavior science. This creates an opportunity to find common ground with old nemeses by revisiting approaches that mainstream researchers have employed in attempting to understand stimulus relations. Below we mention two examples.

First, recall the historical emphasis on explaining the emergence of stimulus relations through some sort of mediation. It might be said that early meditational approaches achieved limited success because they attempted to operate with two unknowns. That is, they sought to understand what organismic variables contribute to the emergence of stimulus relations without properly understanding situational determinants that could provide an alternate explanation. Once basic behavioral research began clarify those situational determinants (e.g., Sidman, 1994), it became possible to productively re-examine the question of mediation.

From the earliest days of stimulus relations research it had been observed that verbally-capable learners sometimes spontaneously name the stimuli presented to them; in fact, the Rexroad (1926) experiment introduced at the start of this essay arose in part because subjects in an earlier study had been observed to do this. Sidman had seen something similar in his work and entertained the notion that this behavior facilitated the development of stimulus relations (Constantine & Sidman, 1975; Sidman, Willson-Morris, & Kirk, 1986). In one of the major theoretical treatises on stimulus relations, Horne and Lowe (1996) subsequently described how the principles of behavior familiar to behavior scientists may account for both the existence of naming and its mediation of the emergence of stimulus relations. Thus, mediation (of a particular type) need not be at odds with a behavioral analysis.

Second, recall that historically, particularly in cognitive psychology, there has been interest in describing already-existing stimulus relations. In recent years behavior scientists have placed increasing attention on understanding the functional properties of these relations. Rather than attempting to map out the structure of elaborate "knowledge networks," however, behavior scientists have systematically examined how familiar stimuli (those which are part of preexisting stimulus relations) affect the formation of, and are incorporated into, new stimulus classes. The key finding in many cases is that familiar stimuli facilitate both directly-taught and derived stimulus relations; for a detailed treatment, see Fields and Arntzen (this issue).

Such efforts matter because behavior science and cognitive psychology have been regarded as arch competitors (e.g., Baars, 1986; Skinner, 1977). A key emphasis in writings on RFT has been the importance of behavior science addressing topics that cognitive psychologists claimed as their special province (Hayes et al., 2001), and this is not merely in order to compete. Zentall et al. (2002) suggested that the behavior-science research strategy of building stimulus classes from the ground up is a natural complement to the cognitive psychology strategy of trying to deconstruct existing classes; if so, then working on common topics of investigation might forge closer relations between the two theoretical communities. Each of the present authors, through his work with stimulus relations, has experienced this potential for rapprochement. Dougher, for example, has received only positive feedback from cognitive psychologists for stimulus-relations research on false memory, a topic on which they have made significant advances (e.g., Guinther & Dougher, 2010, 2014). Critchfield was invited to co-edit a special issue of a cognitive-developmental journal, in which appeared an article on harnessing stimulus relations in instructional design (Critchfield & Twyman, 2014). Barnes-Holmes was recruited to an eclectic psychology department and there collaborates actively with cognitive psychologists; some of the relevant work appears in journals devoted to cognitive and social psychology (e.g., De Houwer, Gawronski, & Barnes-Holmes, 2013; Remue, De Houwer, Barnes-Holmes, Vanderhasselt, & De Raedt, 2013). These examples illustrate the significant potential for interdisciplinary synergy that stimulus relations research creates. See De Houwer (this issue; De Houwer, Hughes, & Barnes-Holmes, 2017) for discussion of a general strategy for finding common ground between behavioral and cognitive researchers.

Concluding Comment

It should now be clear that research on stimulus relations opens vast avenues of empirical, theoretical, and applied inquiry. Figure 6 summarizes several of the themes that have been mentioned in the present essay. There is much, much more to the topic, enough to occupy the interested reader for a long time. Perhaps the critical phrase in that last sentence is "interested reader," because, arguably, there have been too few of those during most of the history of stimulus relations research in behavior-science. For too long this was regarded as a niche domain, one dominated by a few specialists, addressed in only a few journals, and having limited impact on the whole of behavior

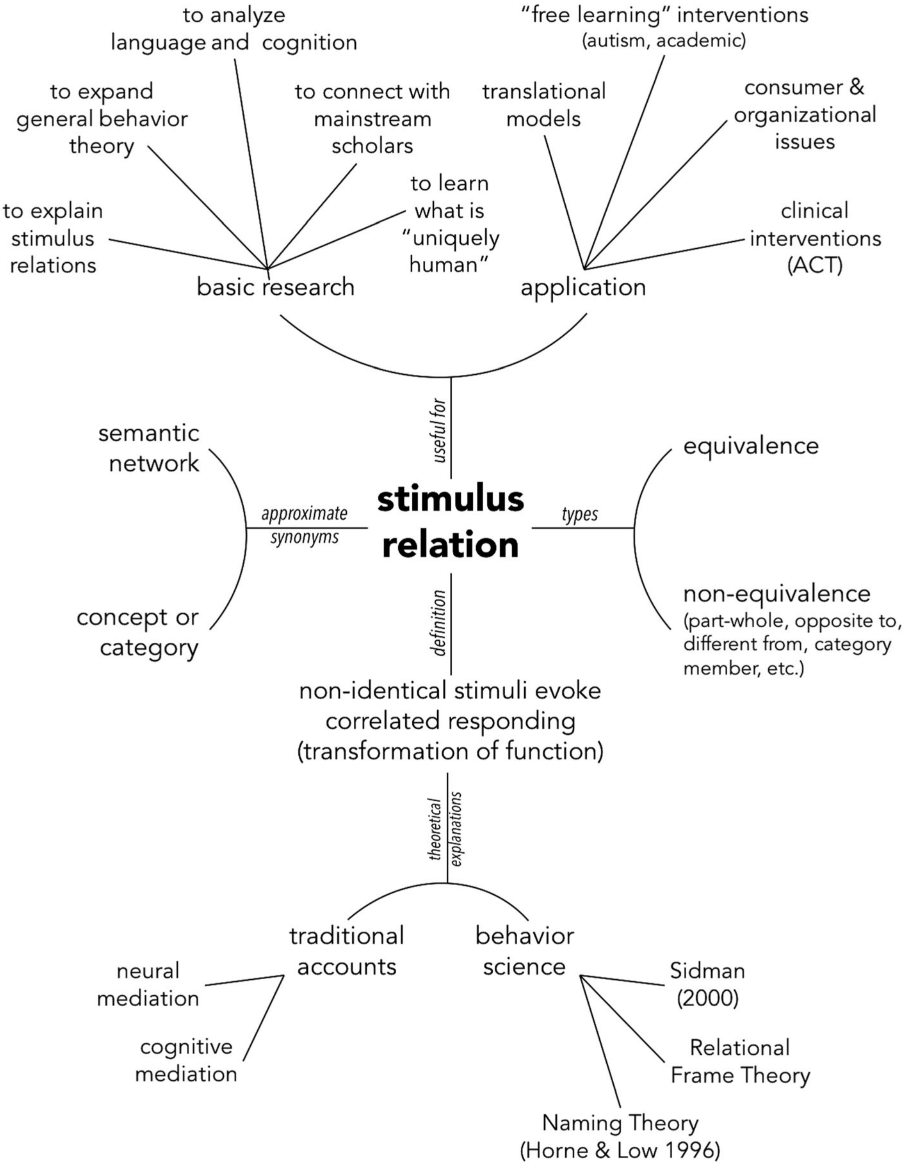

Fig. 6 A "semantic network," or concept map, summarizing some of the stimulus relations in which the concept of "stimulus relations" participates

science. But times are changing. More and more investigators show interest in stimulus relations. Their work appears, not only in most of the major behavior-science journals, but in mainstream psychology and interdisciplinary journals as well. Unlike only a few years ago, stimulus relations concepts are mentioned in many textbooks devoted to teaching behavior principles. For the first time, in 2017 the Behavior Analyst Certification Board began requiring that stimulus relations receive attention in the education of Board Certified behavior Analysts® (https://bacb.com/wp-content/uploads/2017/01

/170113-BCBA-BCaBA-task-list-5th-ed-english.pdf). All of this befits an area of inquiry with demonstrated potential to shake up the status quo of behavior science and its various technological extensions. Indeed, it is not immodest to suggest that today no person can credibly claim the mantle of “behavior scientist” or “applied behavior analyst” without a good working knowledge of stimulus relations (e.g., Critchfield, in press).

A Special Issue Dedicated to Murray Sidman

Something else that should be clear from the present essay is that, within behavior science, Murray Sidman (Figure 7) was a primary vector for the evolution of this research area. Perhaps the greatest testament to Sidman’s seminal work is that, although behavior scientists interested in stimulus relations have produced a huge research literature and addressed many topics of theoretical and social importance, they have only begun to scratch the surface of this multifaceted topic. What Sidman set into motion some 50 years ago looks poised to fuel discoveries for at least the next 50.

That should be enough for any one career, but Sidman, of course, made many other contributions. For example, he wrote the iconic manual of steady-state operant research design, *Tactics of Scientific Research* (Sidman, 1960), and conducted groundbreaking research on negative reinforcement, including by devising a now-eponymous free-operant avoidance procedure that is a staple of research laboratories everywhere (“Sidman avoidance;” Sidman, 1953).

Fig. 7 Murray Sidman. Photo courtesy of the Association for Behavior Analysis International

Around the edges of all of this, Sidman became known to several generations of scholars as the consummate colleague. He visited and encouraged the members of countless laboratories. At professional conferences, he shared his time patiently and generously with any who sought him out. He had an uncanny knack for remembering names and faces of passing acquaintances, and of greeting even total strangers with enthusiasm. You could not interact with him without feeling important. If there is someone in behavior science who did not enjoy interacting with Murray Sidman, we have not met that person.

As we write this, Dr. Sidman is retired from academic work, but his influence continues to be felt daily in the pages of journals that feature the science and technology of stimulus relations. The papers in the present issue both honor and build upon on the foundations that that he established, and we dedicate this issue to Dr. Sidman in the hope that it will, in some small way, convey the debt that so many in behavior science owe him.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Standards This work reports no original empirical research and is not subject to the oversight of any ethical review board.

References

Ameral, V., Bishop, L. S., & Reed, K. M. (2017). Beyond symptom severity: The differential impact of distress tolerance and reward responsiveness on quality of life in depressed and non-depressed individuals. *Journal of Contextual Behavioral Science*, 418–424.

Arntzen, E., Fagerstrøm, A., & Foxall, G.R. (2016). Equivalence classes and preferences in consumer choice. In G.R. Foxall (Ed.) , The Routledge companion to consumer behavior analysis (pp. 65–77). New York, NY, US: Routledge/Taylor & Francis.

Ashcraft, M. H. (1994). *Human memory and cognition* (2nd ed.). New York: Harper Collins.

Augustson, E.M., Dougher, M.J., & Markham, M.R. (2000). Emergence of conditional stimulus relations and transfer of respondent eliciting functions among compound stimuli. *The Psychological Record, 50*, 745–770.

Avdagic, E., Morrissey, S. A., & Boschen, M. J. (2014). A randomised controlled trial of acceptance and commitment therapy and cognitive-behaviour therapy for generalised anxiety disorder. *Behaviour Change, 31*, 110–130.

Baars, B. J. (1986). *The cognitive revolution in psychology.* New York: Guildford.

Baer, D. M., & Sherman, J. A. (1964). Reinforcement control of generalized imitation in young children. *Journal of Experimental Child Psychology, 1*, 37–49.

Barnes-Holmes, D., Keane, J., Barnes-Holmes, Y., & Smeets, P. M. (2000). A derived transfer of emotive functions as a means of establishing differential preferences for soft drinks. *The Psychological Record, 50*, 493–511.

Belisle, J., & Dixon M.R. (in press). Relational Density Theory: Non-linearity of equivalence relating examined through higher-order volumetric-mass-density. *Perspectives on Behavior Science*

Bond, F. W., & Bunce, D. (2003). The role of acceptance and job control in mental health, job satisfaction, and work performance. *Journal of Applied Psychology, 88*, 1057–1067.

Bond, F. W., Hayes, S. C., & Barnes-Holmes, D. (2006). Psychological flexibility, ACT, and organizational behavior. *Journal of Organizational Behavior Management, 26*, 25–54.

Brown, T. (1860). *Lectures on the philosophy of the human mind* (20th ed.). London: William Tegg.

Burckhardt, R., Manicavasagar, V., Batterham, P. J., Hadzi-Pavlovic, D., & Shand, F. (2017). Acceptance and commitment therapy universal prevention program for adolescents: a feasibility study. *Child and Adolescent Psychiatry and Mental Health, 11*, 27.

Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. *Psychological Review, 82*, 407–428.

Cofer, C. N., & Foley Jr., J. P. (1942). Mediated generalization and the interpretation of verbal behavior: I. Prolegomena. *Psychological Review, 49*, 513–540.

Constantine, B., & Sidman, M. (1975). Role of naming in delayed matching-to-sample. *American Journal of Mental Deficiency, 79*, 680–689.

Critchfield, T. S. (in press). Efficiency is everything: Promoting efficient practice by harnessing derived stimulus relations. *Behavior Analysis in Practice*.

Critchfield, T. S., & Twyman, J. S. (2014). Prospective instructional design: establishing conditions for emergent learning. *Journal of Cognitive Education and Psychology, 13*, 201–217.

Daar, J. H., Negrelli, S., & Dixon, M. R. (2015). Derived emergence of WH question–answers in children with autism. *Research in Autism Spectrum Disorders, 19*, 59–71.

Davison, M., & Nevin, J. A. (1999). Stimuli, reinforcers, and behavior: an integration. *Journal of the Experimental Analysis of Behavior, 71*, 439–482.

Deacon, T. W. (1997). *The symbolic species*. New York: Norton.

De Houwer, J., Gawronski, B., & Barnes-Holmes, D. (2013). A functional-cognitive framework for attitude research. *European Review of Social Psychology, 24*, 252–287.

De Houwer, J., Hughes, S., & Barnes-Holmes, D. (2017). Bridging the divided between functional and cognitive psychology. *Journal of Applied Research in Memory and Cognition, 6*, 47–50.

Dewey, J. (1933). *How we think: a restatement of the relation of reflective thinking to the educative process*. Boston: D.C. Heath.

DiClemente, D., & Hantula, D. A. (2000). John Broadus Watson: I/O psychologist. *The Industrial Psychologist, 37*, 47–55.

DiClemente, D. F., & Hantula, D. A. (2003). Applied behavioral economics and consumer choice. *Journal of Economic Psychology, 24*, 589–602.

Dixon, M. R., Belisle, J., McKeel, A., Whiting, S., Speelman, R., Daar, J. H., & Rowsey, K. (2017). An internal and critical review of the PEAK Relational Training System for children with autism and related intellectual disabilities: 2014–2017. *The Behavior Analyst, 40*, 493–521.

Dixon, M. R., Rehfeldt, R. A., Zlomke, K. R., & Robinson, A. (2006). Exploring the development and dismantling of equivalence classes involving terrorist stimuli. *The Psychological Record, 56*, 83–103.

Dodwell, P. C. (2000). *Brave new mind: a thoughtful inquiry into the nature and meaning of mental life*. Oxford: New York.

Dougher, M. J., Augustson, E., Markham, M. R., Greenway, D. E., & Wulfert, E. (1994). The transfer of respondent eliciting and extinction functions through stimulus equivalence classes. *Journal of the Experimental Analysis of Behavior, 62*, 331–351.

Dougher, M.J., Perkins, D.R., Greenway, D., Koons, A., & Chiasson, C. (2002). Contextual control of equivalence-based transformation of functions. *Journal of the Experimental Analysis of Behavior, 7*, 63–93.

Dugdale, N., & Lowe, C. F. (2000). Testing for symmetry in the conditional discriminations of language-trained chimpanzees. *Journal of the Experimental Analysis of Behavior, 73*, 5–22.

Dymond, S., & Rehfeldt, R. A. (2000). Understanding complex behavior: the transformation of stimulus functions. *The Behavior Analyst, 23*, 239–254.

Dymond, S., & Roche, B. (2013). *Advances in relational frame theory: research and application*. Oakland, CA: New Harbinger.

Dymond, S., Schlund, M. W., Roche, B., & Whelan, R. (2014). The spread of fear: symbolic generalization mediates graded threat-avoidance in specific phobia. *Quarterly Journal of Experimental Psychology, 67*, 247–259.

Guercio, J., Podolska-Schroeder, H., & Rehfeldt, R. A. (2004). Using stimulus equivalence technology to teach emotion recognition to adults with acquired brain injury. *Journal of Brain Injury, 18*, 593–601.

Guinther, P. M., & Dougher, M. J. (2010). Semantic false memories in the form of derived relational intrusions following training. *Journal of the Experimental Analysis of Behavior, 93*, 329–347.

Guinther, P. M., & Dougher, M. J. (2014). Partial contextual control of semantic false memories in the form of derived relational intrusions following training. *The Psychological Record, 64*, 457–473.

Griffee, K., & Dougher, M. J. (2002). Contextual control of stimulus generalization and stimulus equivalence in hierarchical categorization. *Journal of the Experimental Analysis of Behavior, 78*, 433–447.

Hann, K. E., & McCracken, L. M. (2014). A systematic review of randomized controlled trials of acceptance and commitment therapy for adults with chronic pain: outcome domains, design quality, and efficacy. *Journal of Contextual Behavioral Science, 3*, 217–227.

Hantula, D. A., DiClemente, D. F., & Rajala, A. K. (2001). Outside the box: the analysis of consumer behavior. In L. Hayes, J. Austin, R. Houmanfar, & M. Clayton (Eds.), *Organizational change* (pp. 203–223). Reno, NV: Context Press.

Hayes, S. C., Barnes-Holmes, D., & Roche, B. (Eds.). (2001). *Relational frame theory: a post-Skinnerian account of human language and cognition*. New York: Springer.

Hayes, S. C., Bunting, K., Herbst, S., Bond, F. W., & Barnes-Holmes, D. (2006). Expanding the scope of organizational behavior management: relational frame theory and the experimental analysis of complex human behavior. *Journal of Organizational Behavior Management, 26*, 1–23.

Horne, P. J., & Lowe, C. F. (1996). On the origins of naming and other symbolic behavior. *Journal of the Experimental Analysis of Behavior, 65*, 185–241.

Hughes, S., & Barnes-Holmes, D. (2014). Associative concept learning, stimulus equivalence, and relational frame theory: Working out the similarities and differences between human and nonhuman behavior. *Journal of the Experimental Analysis of Behavior, 101*, 156–160.

Hull, C. L. (1939). The problem of stimulus equivalence in psychological theory. *Psychological Review, 46*, 9–30.

James, W. (1890/1950). *The principles of psychology,* Vols 1 & 2. Reprint edition. New York: Dover.

Kastak, C. R., Schusterman, R. J., & Kastak, D. (2001). Equivalence classification by California sea lions using class-specific reinforcers. *Journal of the Experimental Analysis of Behavior, 76*, 131–158.

Kelleher, R. T., & Gollub, L. R. (1962). A review of positive conditioned reinforcement. *Journal of the Experimental Analysis of Behavior, 5*, 543–597.

Keller, F. S., & Schoenfeld, W. N. (1950). *Principles of psychology.* New York: Appleton-Century-Crofts.

Kluver, H. (1933). *Behavior mechanisms in monkeys*. Chicago: University of Chicago Press.

Kyonka, E. G. E., & Subramamian, S. (in press). Translating behavior analysis: a spectrum rather than a roadmap. *Perspectives on Behavior Science*.

Lashley, K. S. (1942). An examination of the "continuity theory" of discriminative learning. *Journal of General Psychology, 26*, 241–265.

Lane, S.D., & Critchfield, T.S. (1998). Increasing the generativity of identity-based procedures for establishing arbitrary conditional relations. *The Psychological Record, 48*, 457–479.

LeBlanc, L. A., Miguel, C. F., Cummings, A. R., Goldsmith, T. R., & Carr, J. E. (2003). The effects of three stimulus-equivalence testing conditions on emergent US geography relations of children diagnosed with autism. *Behavioral Interventions, 18*, 279–289.

Locke, J. (1690/1997). *Essay concerning human understanding*. Penguin Reprint Edition (R. Woolhouse, Ed.). New York: Penguin Putnam.

Luciano, C., Gomez Becerra, I., & Rodrigue-Valverde, M. (2007). The role of multiple-exemplar training and naming in establishing derived equivalence in an infant. *Journal of the Experimental Analysis of Behavior, 87*, 349–365.

Mace, F. C., & Critchfield, T. S. (2010). Translational research in behavior analysis: historical traditions and imperative for the future. *Journal of the Experimental Analysis of Behavior, 93*, 293–312.

Mach, E. (1886/1914). The analysis of sensations and the relation of the physical to the psychical. Translated by C.M. Williams. Chicago: Open Court.

Maraccini, A. M., Houmanfar, R. A., & Szarko, A. J. (2016). Motivation and complex verbal phenomena: implications for organizational research and practice. *Journal of Organizational Behavior Management, 36*, 282–300.

McCosh, J. (1886). *Psychology: the cognitive powers*. New York: Charles Scribner's Sons.

McIlvane, W. J., & Dube, W. V. (2003). Stimulus control topography coherence theory: foundations and extensions. *The Behavior Analyst, 26*, 195–213.

McLay, L. K., Sutherland, D., Church, J., & Tyler-Merrick, G. (2013). The formation of equivalence classes in individuals with autism spectrum disorder: a review of the literature. *Research in Autism Spectrum Disorders, 7*, 418–431.

Mill, J. (1829/1869). *Analysis of the phenomena of the human mind*. Annotated Edition, Vol. 1. (A. Bain, A. Findlater, G. Grote, & J.S. Mill, Eds.). London: Longman Green Reader and Dyer.

Ming, S., & Stewart, I. (2017). When things are not the same: a review of research into relations of difference. *Journal of Applied Behavior Analysis, 50*, 429–455.

Morgan, C. L. (1903). *An introduction to comparative psychology* (Revised ed.). London: Walter Scott.

Murphy, C., & Barnes-Holmes, D. (2009). Derived more-less relational mands in children diagnosed with autism. *Journal of Applied Behavior Analysis, 42*, 253–268.

Reese, H. W. (1968). *The perception of stimulus relations: discrimination learning and transposition*. New York: Academic Press.
Rehfeldt, R. A. (2011). Toward a technology of derived stimulus relations. *Journal of Applied Behavior Analysis, 44*, 109–119.
Remue, J., De Houwer, J., Barnes-Holmes, D., Vanderhasselt, M., & De Raedt, R. (2013). Self-esteem revisited: performance on the relational self-assessment procedure as a measure of self- versus ideal self-related cognitions in dysphoria. *Cognition and Emotion, 27*, 1441–1449.
Rexroad, C. N. (1926). Verbalization in multiple choice reactions. *Psychological Review, 33*, 451–458.
Rodgers, C. (2002). Defining reflection: another look at John Dewey and reflective thinking. *Teachers College Record, 104*, 842–866.
Sidman, M. (1953). Avoidance conditioning with brief shock and no exteroceptive warning signal. *Science, 118*, 57–58.
Sidman, M. (1960). *Tactics of scientific research*. New York: Basic Books.
Sidman, M. (1971). Reading and auditory-visual equivalences. *Journal of Speech and Hearing Research, 14*, 5–13.
Sidman, M. (1986). Functional analysis of emergent verbal classes. In T. Thompson & M. D. Zeiler (Eds.), *Analysis and integration of behavioral units* (pp. 213–245). Hillsdale, NJ: Erlbaum.
Sidman, M. (1994). *Equivalence relations and behavior: a research story*. Boston: Authors Cooperative.
Sidman, M. (1995). K&S: then and now. In F.S. Keller and W.N. Schoenfeld, *Principles of psychology*(unpaginated foreward). B.F. Skinner Reprint Series (J.S. Vargas, Ed.). Cambridge, MA: B.F. Skinner Foundation.
Sidman, M. (2000). Equivalence relations and the reinforcement contingency. *Journal of the Experimental Analysis of Behavior, 74*, 127–146.
Sidman, M., Rauzin, R., Lazar, R., Cunningham, S., Tailby, W., & Carrigan, P. (1982). A search for symmetry in the conditional discriminations of rhesus monkeys, baboons, and children. *Journal of the Experimental Analysis of Behavior, 37*, 23–44.
Sidman, M., Willson-Morris, M., & Kirk, B. (1986). Matching-to-sample procedures and the development of equivalence relations: the role of naming. *Analysis and Intervention in Developmental Disabilities, 6*, 1–19.
Skinner, B. F. (1950). Are theories of learning necessary? *Psychological Review, 57*, 193–216.
Skinner, B. F. (1953). *Science and human behavior*. New York: Simon & Schuster.
Skinner, B. F. (1977). Why I am not a cognitive psychologist. *Behavior, 5*, 1–10.
Smith, E. E., Rips, L. J., & Shoben, E. J. (1974). Semantic memory and psychological semantics. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 8, pp. 1–45). New York: Academic Press.
Smith, K. U. (1936). Visual discrimination in the cat: III. The relative effect of paired and unpaired stimuli in the discriminative behavior of the cat. *The Pedagogical Seminary and Journal of Genetic Psychology, 48*, 29–57.
Spencer, W. (1883). *A system of synthetic philosophy, vol. IV. The principles of psychology*. New York: Appleton.
Stevens, S. S. (1951). *Handbook of experimental psychology*. New York: Wiley.
Stewart, I., Barnes-Holmes, D., Roche, B., & Smeets, P. M. (2002). A functional-analytic model of analogy: a relational frame analysis. *Journal of the Experimental Analysis of Behavior, 78*, 375–396.
Tolman, E. C. (1938). The determiners of behavior at a choice point. *Psychological Review, 45*, 1–41.
Torneke, N. (2010). *Learning RFT: an introduction to relational frame theory and its clinical application*. Oakland, CA: New Harbinger Publications.
Urcuioli, P. J. (2008). Associative symmetry, antisymmetry, and a theory of pigeons' equivalence-class formation. *Journal of the Experimental Analysis of Behavior, 90*, 257–282.
Van der Gucht, K., Griffith, J. W., Hellemans, R., Bockstaele, M., Pascal-Claes, F., & Raes, F. (2017). Acceptance and commitment therapy (ACT) for adolescents: outcomes of a large-sample, school-based, cluster-randomized controlled trial. *Mindfulness, 8*, 408–416.
Watt, A., Keenan, M., Barnes, D., & Cairns, E. (1991). Social categorization and stimulus equivalence. *The Psychological Record, 41*, 33–50.
Weil, T. M., Hayes, S. C., & Capurro, P. (2011). Establishing a deictic relational repertoire in young children. *The Psychological Record, 61*, 371–390.
Wheeler, R. H. (1929). *The science of psychology: an introductory study*. New York: Crowell.
Whelan, R., & Barnes-Holmes, D. (2004). The transformation of consequential functions in accordance with the relational frames of same and opposite. *Journal of the Experimental Analysis of Behavior, 82*, 177–195.

Zentall, T. R., Galizio, M., & Critchfield, T. S. (2002). Categorization, concept learning, and behavior analysis: an introduction. *Journal of the Experimental Analysis of Behavior, 78*, 237–248.

Zettle, R. D., Hayes, S. C., & Barnes-Holmes, D. (2016). *The Wiley handbook of contextual behavioral science*. New York: Wiley.

Zinn, T. E., Newland, M. C., & Ritchie, K. E. (2015). The efficiency and efficacy of equivalence-based learning: a randomized controlled trial. *Journal of Applied Behavior Analysis, 48*, 865–882.