Thinking Through Text Comprehension I: Foundation and Guiding Relations

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Abstract

Reading comprehension can be considered a complex human performance involving two integrated repertoires: a verbal repertoire and an investigative (generative) repertoire. This paper describes the theoretical framework that formed the guiding foundation for the development of Headsprout® Reading Comprehension and to our approach to understanding and teaching thinking.

Keywords

dimensional, instructional, textual, extended tact, abstract, private events, verbal repertoire, investigative repertoire, comprehension

That is all fine and well in practice,

…but how does it work in theory?

–popular University of Chicago t-shirt

Each seated at a computer, two boys, Jeffrey and John, are asked to read a passage, read a question about the passage, and then choose the best answer from three possible choices. First, we see Jeffrey move his eyes while looking at the passage; then, we see him move his eyes in a way that directs his gaze toward the question. He moves the mouse connected to the computer and we see the on-screen cursor move to the question, then down to each possible answer, moving slowly from one to another. We see the cursor move to the passage, move back and forth in one particular spot in the passage, and then move back to the possible answers. The cursor hovers over one of the possible answers, and we see the mouse button pressed. A mark on the display screen appears. We see a confirmation that the answer is correct.

Next, we see John move his eyes while looking at the passage; then, we see him move his eyes in a way that directs his gaze toward the question. He moves the mouse connected to the computer and we see the on-screen cursor move to the question, then down to each possible answer, moving slowly from one to another. We see him pause and then move the mouse so that the cursor hovers over one of the possible answers, and we see the mouse button pressed. A mark on the display screen appears. We see that the answer is not correct.

From the observable activities, it is not easy to account for what is governing the behavior of each boy. We notice a difference in cursor movement, and we see that the boy who moved the cursor to the passage prior to selecting the answer correctly answered the question. If we want to increase the frequency of John's correct answers, should we simply reinforce cursor movements to an area of the passage? We know that that this behavior alone is unlikely to produce success. But why?

The immediate answer is that there is something occurring that we cannot see. It is private: that is, it is accessible only to Jeffrey and John. We can guess at what might be happening. We can also guess that what is happening for Jeffrey is likely to be different than what is happening for John. Both appear to be doing what can be called thinking. And further, this thinking seems to play a more important role in getting the answer correct than do any of the behaviors we can observe. Since Jeffrey and John are two fictional boys, we can take a fictional journey within their skin and share access to their private events.

Let's begin with John. As he moves his eyes along the text, he "hears" each word of text as it is read.

> *"It was the first day of summer. Sam woke up early and ran outside, wondering what he should do first. Then he saw his new bike leaning against the tree. When Sam saw his new bike, he grinned."*

But there is more. John "sees" Sam and what he is doing. When John reads that the "new bike [is] leaning against the tree," he sees a sparkling bicycle, not an old, dirty one, and he sees it on an angle against a tree, not held up by a kickstand. John may also feel some of Sam's excitement.[1]

Next, John reads the question, "How did Sam feel when he saw his new bicycle?" Again, he hears the words. He then reads the possible answers: "sad, happy, funny." But this time he also hears himself say, "It wants me to guess at how Sam feels. I think funny sounds good." He then puts a mark next to "funny."

Jeffrey has a different experience. Like John, he visualizes Sam and what he is doing. When Jeffrey reads that the "new bike [is]

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1 See philosopher Ted Cohen's (2008) book, Thinking of Others: On the Talent for Metaphor, for an outstanding treatment of the relation of text to emotions and personal perspective.

leaning against the tree," he too sees a sparkling bicycle, not an old, dirty one, and he sees it on an angle against a tree, not held up by a kickstand. And Jeffrey, too, may feel some of Sam's excitement.

Next, Jeffrey reads the question, "How did Sam feel when he saw his new bicycle?" Again, he hears the words as he reads. He then reads, "sad, happy, funny." But Jeffrey hears himself say, "It wants me to find how Sam feels. I'll look back in the passage to see if I can find 'sad,' 'happy,' or 'funny.' No… no… I can't find any of those words in the passage. I'll have to look for clue words that will help me think about how Sam was feeling. Here it says, 'When Sam saw his new bike, he grinned.' Hmmm, 'grinned.' That makes me think Sam was feeling happy, and 'happy' is one of the possible answers. I'll put a mark next to 'happy.'"

It appears that what determined where each boy put their mark was their thinking. One boy more or less guessed, while the other systematically thought about what needed to be done and did it. But was their thinking responsible? The boys may experience precisely what was described, but does that account for the difference in their answers? Why did each think something different, and what determines that? And if we want to improve learner performance, what needs to be done?

What we just examined is an instance of what may be called reading comprehension. In fact, it is an example of what has come to be called inferential comprehension—that is, the answer to the question was not specifically found in the passage. Our learners had to figure it out.

But we are getting a little ahead of ourselves. First, a primary question needs to be asked: "What does it mean to comprehend text?" Goldiamond and Dyrud (1966) attacked this problem with the following illustration. They suggested that if one, in front of a room full of people, writes on a blackboard, "look at the ceiling," some may verbalize "look at the ceiling," while others may tilt their heads and look up. The ones looking up demonstrate comprehension. That is, we observe a contingency-specific (evaluated) change in a referent behavior as a function of seeing the text. For those who simply spoke the words in order, we cannot draw the same conclusion. They may simply be able to see and say each word. This is a distinction reading teachers make between comprehension and decoding, and it's why oral reading is not taken as the only indicator that a learner can read. All reading comprehension tests assess this difference.

Changes in referent behaviors as a function of textual stimuli fall into many different categories. These changes begin at the level of the word. For example, each word read is made up of phonetic elements that together provide an occasion for behavior that differs depending on their sequence ("dog" versus "god," for example). Further, sequences of letters and of words have effects that vary with differences in their sequence ("bike saw new Sam his" versus "Sam saw his new bike"), as well as other autoclitic effects (see Skinner, 1957). Accordingly, we evaluate whether or not something is understood by testing for specified changes in referent behaviors as a function of changes in the text. If a learner sees the letters c-a-t and then says "cat," we have textual responding, or decoding. If the learner points to a picture of a cat, we have a different change in referent behavior that can also be evaluated, a tact (after Skinner, 1957).

We can go further. We can assess a range of relations potentiated (after Goldiamond & Thompson 1967/, 2004) by textual stimuli. We can test for generic extension by providing multiple examples that include a range of different cats (Skinner, 1957, p. 91). We can test for abstract tacts by including foxes of similar size and color to see if they are called "cat" (after Skinner, 1957, p. 107). We can show that the learner "understands" the concept of "cat" by providing a juxtaposed sequence of examples and non-examples of cat such that the learner points to all the cats and none of the other similar creatures, such as lemurs or skunks (see Tiemann & Markle, 1990, chapters 4 and 5). We can test for metonymical extension by asking for all things that go with Halloween and seeing whether a black cat is selected (Skinner, 1957, p. 99). We can test separately for defining attribute features that, when added to mammalian features, distinguish a cat from a skunk. That is, the occasion provided by seeing a cat inherits all the critical features of mammals (the superordinate class) and includes defining features of its own to make a separate subordinate class (Layng, 2005, 2007; Tiemann & Markle, 1980). We can test for such abstract tact "inheritance" by saying, "choose the mammal with big eyes relative to its head size and whiskers and upright ears," and seeing if the learner selects a cat from among other mammals. And as Markle (1978) noted, we can test for the increased probability of occurrence of any of these and other relations in a "conceptual network" when any one extended relation is made more likely to occur than another by manipulating the instructional context (see below).

This paper, the first in a series of three, describes the theoretical framework that guided our efforts in building an online software program that teaches typical schoolchildren how to think about and comprehend text. Subsequent papers detail the analysis of the stimulus-control relations required (Sota et al., 2011) and describe some of the practical programing considerations and procedures developed (Leon et al., 2011).

THE RELATION OF THE WRITER TO THE READER

To the extent that the printed text overlaps with the verbal repertoire of the reader, one can be guided by the same (or similar) stimulus-control relations that guide the writer. Such guidance (after Donahoe & Palmer, 2004) is provided not so much by the dimensional control presented by the text—that is, the printed words—but by the instructional control those words exert over the reader's behavior—that is, the reader's history of responding to those words. Such instructional control serves to restrict reader response alternatives to match those of the writer more closely. The distinction between instructional and dimensional control (see Goldiamond, 1966) or guidance is important for understanding how we may think about text.

DIMENSIONAL AND INSTRUCTIONAL GUIDANCE OF BEHAVIOR

Goldiamond (1966, 1967/2004) described two types of guidance that make up any stimulus-control topography (see Ray, 1969; Ray & Sidman, 1970). These include both to "what" one responds and "how" one responds. The "what" can be classified as dimensional control—S^Dd—and the "how" as instructional control —S^Di —which includes abstractional control (S^Da). S^Di,a should not be understood solely as guidance by instructions or rules, but includes those relations (see Figure 1). By treating dimensional and instructional guidance separately, one can set up and more precisely test for the maintenance and transfer of many different aspects of stimulus control. These variations include:

1. maintaining S^{D}d and S^{D}i guidance across contexts: Saying "ball" in the presence of a ball in the house and at the playground;
2. maintaining S^{D}d guidance while changing S^{D}i guidance: Holding the ball and first asking for its color, then its weight, its size, etc.;
3. changing S^{D}d guidance while maintaining S^{D}i guidance: Saying "ball" in the presence of basketballs, baseballs, soccer balls, etc.; and
4. changing S^{D}d guidance while also changing S^{D}i guidance: Saying "ball" in the presence of a ball, saying "used to play a game" in the presence of a ball, and then saying "used to play a game" in the presence of a hockey puck.

This formulation may not be familiar to some readers and, unfortunately, the treatment here is necessarily brief. However, an extended discussion of these relations and their programing can be found in Goldiamond (1966) and Goldiamond and Thompson (1967/2004).

Here is a procedural example:

> *The procedure is actually quite simple. (1) First you arrange things into different groups depending on their makeup. (2) Of course, one pile may be sufficient depending on how much there is to do. (3) If you have to go somewhere else due to lack of facilities that is the next step, otherwise you are pretty well set. (4) It is important not to overdo any particular endeavor. (5) That is, it is better to do too few things at once than too many. (6) In the short run this may not seem important, but complications from doing too many can easily arise. (7) A mistake can be expensive as well. (8) The manipulation of the appropriate mechanisms should be self-explanatory, and we need not dwell on it here. (9) At first the whole procedure will seem complicated. (10) Soon, however, it will become just another facet of life. (11) It is difficult to foresee any end to the necessity for this task in the immediate future, but then one can never tell. (from Walhberg & Magliano, 2004)*

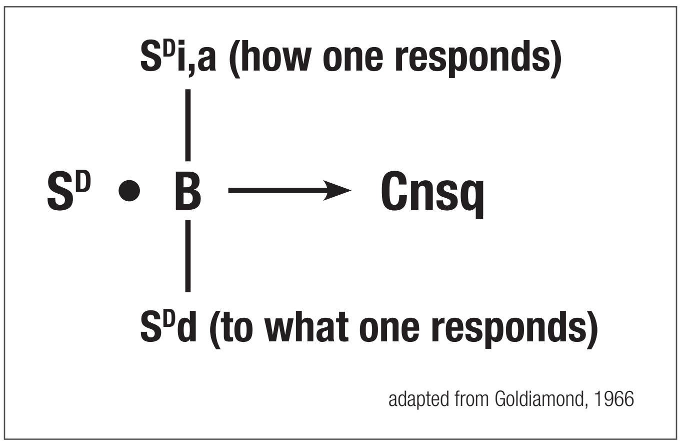

Figure 1. A stimulus-control topography features two types of guidance: dimensional guidance and instructional guidance. To what one responds—S^{D}, not S^{Δ}—is the dimensional guidance, and how one responds, the response topography, and to what features defines the instructional guidance (as determined by a consequential contingency). S^{D}i guidance can broadly be considered as any stimuli which are either components of a stimulus or accompany a stimulus that restricts response alternatives in accord with the contingency requirement for reinforcement. How we respond to a chess piece is guided not only by the physical characteristics of the piece (S^{D}d, S^{D}i; the Knight moves in a specific pattern), but conditionally given its position (S^{D}i) on the chess board. The S^{D}i may be intertwined (S^{D}a) with the S^{D}d, as when one can distinguish a chair from a non-chair based upon a unique subset of features. The S^{D}i may also arise through having a common response to a set of stimuli or occur through a history of pairing stimuli. It can be established through stimulus variation (abstractional—only responses to red are reinforced) and other procedures, or previously established instructional guidance may be transferred through instruction, as in the request to "respond to the color of a stimulus" (rather than its weight, etc.).

Make much sense? Now look at the footnote[2] and reread it. The changed S^{D}i restricts the reader's response alternatives to more closely match those of the writer and makes this "categorical match" more likely—even though there was no change in the S^{D}d. Because the reader has established extended verbal relations as a speaker, his or her verbal repertoire is arranged and rearranged by the changing S^{D}i guidance, making one type of tact extension more likely than another. Ferster and Perrott (1968) spoke of a similar process when they described how one learns from a lecture:

> *It may seem a paradox that the listener needs essentially the same repertoire as the speaker if the communication is to be effective. What, then, was communicated? Actually, an instruction was communicated, a rearrangement of existing verbal behavior so that new combinations can occur. (p. 437)*

The phrase "How to wash clothes" provides an S^{D}i that brings the verbal repertoire of the reader into contact with the categories described in the text. This S^{D}i restricts readers' responses to behaviors having to do with laundry, thus narrowing the reader's response alternatives and thereby increasing the overlap between writer and reader stimulus-control relations. But there is more. The reader may now see a washing machine, hear a dryer, or experience the fresh smell of recently laundered clothes. The response alternatives may be restricted to a particular range of related responses. Stated differently, certain stimulus-control topographies are made more likely than others. This function of S^{D}i guidance is important to understanding how we may be thinking about the text we read.

RESPONDING TO S^{D}I AND THE ABSENCE OF S^{D}D

Verbal stimuli, spoken and textual, can provide S^{D}i guidance over repertoires established when both the S^{D}d and the S^{D}i were present. One can ask someone to pretend they are driving a car. We may see the individual grasp an invisible steering wheel, adjust their feet, and extend their arms, though no steering wheel is present. We might also observe subtle movements of the hands as if one is adjusting the car's direction while driving. If we shout, "There's a cat in the road!" we may see a sudden movement as to indicate a rapid turning of the wheel. We may even notice an "emotional" response indicated by raised eyebrows

2 S^{D}i: How to wash clothes.

and widening eyes. But there is no steering wheel and no cat is present. What we have done is to potentiate S^Di guidance over behavior similar to that which may exist when there is also S^Dd guidance—that is, when we are actually driving. S^Di guidance in the absence of S^Dd guidance is similar, but not the same as that which occurs with S^Dd guidance. This difference has been noted in discussions of rule-established behavior, where behavior is primarily under S^Di guidance (Skinner, 1966). This is an important distinction. Behavior under S^Di guidance in the absence of an S^Dd is different than when the S^Dd is present, even when the observed topography may initially look the same. Responding guided by S^Di in the absence of S^Dd may cause some to conclude that we are responding to a private stimulus, when in fact we are simply responding to S^Di guidance.

A demonstration we have used in the classroom can illustrate this difference. We write the word "STRENGTH" on a blackboard. After looking at the word for a couple of minutes, we ask that half the class close their eyes and visualize the word: that is, see it privately. We ask those with their eyes closed who can readily see it to raise their hands. Next we pick one or more people from the audience, confirm that they can clearly see the word, and ask them to start with the last letter and say each letter in the word: H T G N E R T S. Unless one has had special training, this is quite difficult to do. Now, we ask audience members with their eyes wide open and looking at the word to do the same. We observe quite a different outcome. We maintain that there is no word being privately looked at. What we have is the behavior of seeing under S^Di guidance.

This is not an altogether new interpretation. As Skinner (1963), in perhaps his most complete treatment of private events, Behaviorism at Fifty, observes, "It took man a long time to understand that when he dreamed of a wolf, no wolf was actually there. It has taken him much longer to understand that not even a representation of a wolf is there" (p. 955). As noted earlier, S^Di guidance alone is quite different than joint S^Dd/S^Di guidance of seeing. With S^Dd present, we can readily respond to an S^Di that requires naming letters seen. This is not as likely with S^Di guidance alone. Since there is no private stimulus, what we often observe is the recurrence of a spelling repertoire in order to meet the request to read the word last letter to the first. People will often spell the word aloud, and after getting to the letter prior to H, say "T" and repeat the process until all the letters are said. This is never observed for those whose eyes are open.

The private seeing of the word "strength" is part of the behavior of seeing; it does not require something seen (Skinner, 1963), thus, perhaps, accounting for the ephemeral nature of private events. The episodes of "fleeting" thoughts, images, sounds, etc., may simply be reflections of behavior under fleeting S^Di guidance in the absence of an S^Dd.

What is "heard," "thought," or even "seen" while reading may be the changes in response probabilities occasioned by changes in instructional guidance over the reader's behavior that have been established by a past contingent history. Importantly, this may include hearing words read. That is, there is no need to assume that the words privately "heard" while reading are first privately "said." Just as there is no private image of a word required for a word to be seen, no word needs to be privately spoken for a word to be privately heard. A more parsimonious account may be simply to assume the words on the page provide S^Di guidance over yet another class of behavior, hearing words in this case.[3] Accordingly, there may be no subvocal speech, as is often conceptualized.[4]

This raises a question: how is complex textual guidance established and how can it be taught? Two separate repertoires appear to be required. The first consideration is that a reader verbal repertoire exists that overlaps with what is written. The second consideration is that an investigatory repertoire exists that can increase the likelihood of a verbal repertoire reorganization needed to meet contingency requirements (cf Markle, 1981).

THE VERBAL REPERTOIRE OF THE READER AND READING COMPREHENSION

It is essential that the verbal repertoire of the reader overlap with what the writer has written. One problem confronted by those interested in teaching reading comprehension is ensuring that the necessary verbal repertoire is indeed in place. Part of the answer lies in work on establishing functional and equivalence classes (e.g., Wirth & Chase, 2002). This work is most useful in understanding how metonymical extension may occur. That is, how can stimuli that share no defining features (as opposed to generically extended tacts) be brought under the same S^Di guidance? This is an important question: the printed text "stoplight" shares no properties with an actual stoplight. Such guidance needs to be directly taught. Further, we can teach stopping, saying "stop," and writing "stop" when the stoplight is seen. In this case, procedures derived from the equivalence literature can be quite helpful (e.g., Sidman, 1994).

We can further extend the S^Di guidance by making our stopping responses to a range of stimuli that occasion stopping, a "disjunctive concept" (after Bruner, Goodnow, & Austin, 1956). A policeman with a raised hand, a stopped school bus, flashing lights at a railroad crossing, etc., are all stimuli that occasion stopping. None of these share stimulus features, yet they do share common response features: stated differently, they have become functionally equivalent (from Goldiamond, 1966; see Figure 2). In discussing such stimulus classes, Goldiamond (1962) observed that "once a class is established, contingencies applied to one member of a class tend to affect other members of the class" (p. 303).

We may, however, be able to group these stimuli in the class of "dangerous" driving situations or in terms of the situations for which drivers may incur a penalty if they do not stop. Here we

3 This account shares some similarities with Saussure's ([1916] 1983) relational conception of meaning and his analysis of the role of the signifier (the form the stimulus takes) and the signified (the concept it represents) as features of textual understanding. And further, the approach suggested here may perhaps provide a useful unifying framework for those who debate the material versus purely psychological existence of the signifier. It is both and it is neither: that is, the relation resides in the consequential contingencies of which it is a part. Thanks to Zachary Layng for bringing this to our attention.

4 Changes in muscular movements involved with speaking may likewise come under S^Di guidance and accompany reading even though nothing is actually said. Such observations may be interpreted as yet another response class under S^Di guidance.

Adapted from Goldiamond & Thompson ([1968] 2004)

Figure 2. Disjunctive relations with common response. The class "stimuli that occasion stopping (S^Di)" can be described by a set of stimuli (S^Dd) in whose presence stopping has been reinforced.

change the S^Dd to include the contingency into which these stimuli may enter. That is, the entire flashing road sign–stop–avoid a crash relation is tacted. Dangerous situations may describe an abstract tact: that is, it may have a set of common features (likely involving harmful outcomes)—S^Di—that may occasion its use. Further, the abstract tact can extend guidance along a vast range of varying features of changing S^Dds, thus creating the "concept" (see Figures 3 & 4) of "dangerous." Accordingly, we may find instances where metonymical tacts can either intertwine with or be superseded by abstract tact guidance by first changing S^Dd guidance to include an observed outcome and then changing S^Di from "respond to stimuli where a common response is required" to "respond to stimuli when driving where there may be a potential harmful outcome." [5]

Interestingly, Bruner, Goodnow, and Austin (1956) noted in their classic book *A Study of Thinking* that their subjects tended to abhor disjunctive concepts and would gravitate to conjunctive classification whenever possible. This is important because while the topography of a response may be similar, the response effort to learn disjunctive relations may be much greater than for conjunctive. It may even suggest that little human categorical responding involves "pure" disjunctive equivalence relations. Accordingly, we may observe individuals giving stimuli common names or responding to a common consequence. Further, procedures that are good for establishing (disjunctive) metonymical relations, as found in the stimulus equivalence and related areas (see Figure 5), may not be as effective at establishing (conjunctive) abstract relations as are other procedures. For example, guidance by "larger than" may perhaps be established through a stimulus-equivalence or RFT procedure or taught as a "concept" based on a sequence featuring a carefully analyzed rational set of juxtaposed examples and non-examples.

What is required to establish conjunctive relations is not

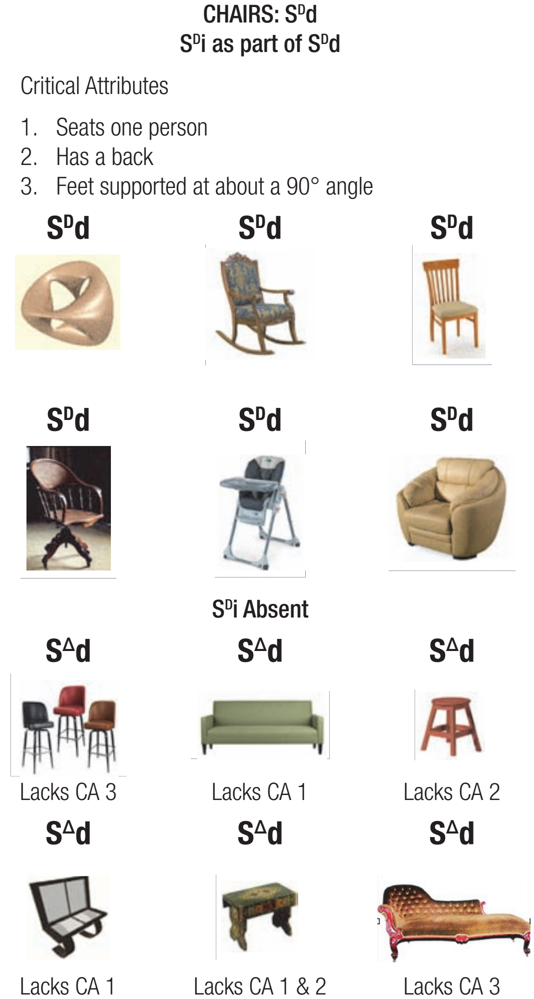

Figure 3. Conjunctive relations or concepts. Examples of chairs (S^Di: seats one person, has a back, legs supported at about 90 degrees [CA 1, CA 2, and CA 3]) may be juxtaposed with non-chairs, such as stools, benches, couches, love seats, etc., displaying varying features such as number of legs, material, etc. S^Di,a guidance can arise by reinforcing saying "chair" only in the presence of chairs or can be established by providing a written list of the attributes (S^Di) in advance. When saying "chair" occurs only as a response to chairs and not to other similar furniture, both S^Dd and S^Di guidance has been established over the behavior of saying (the abstract tact) "chair."

only sequences containing multiple exemplars, but sequences containing multiple juxtaposed non-exemplars (Markle, 1978; Markle & Tiemann, 1969, 1974; Tiemann & Markle, 1990; also see Englemann & Carnine, 1991) in very carefully programed sequences (Markle, 1991). From the perspective of those interested in teaching children to comprehend text, the formulation presented here has led to exciting teaching possibilities and the development of new approaches to teaching "vocabulary" (see Sota et al., 2011 and Leon et al., 2011).

Sequences of words also have autoclitic effects that must be considered (cf. Ferster & Perrott, 1968). Some of these relational autoclitic functions depend on abstract tact guidance and the range of what might be "thought about" on generic extension to exemplars. For example, in the sentence, "The dog believes that he will be fed when the refrigerator door is open," we see a range of abstract tacts: dog, believe, fed, refrigerator, door, and open. In that sentence, "believes" provides the minimal tact (after Skinner, 1957, p. 333) that sets up the autoclitic frame "X

5 We can go even further and program feature and S^Di inheritance hierarchies (Layng, 2005; Markle & Tiemann, 1980) and other forms of superordinate or contextual S^Di guidance (see, for example, DeRosse & Fields, 2010) to facilitate the rapid extension/transfer of S^Di guidance to new S^Dd stimuli.

Figure 4. When we change the particular S^Dd to one the observer has never seen before and find the observer still says "chair", but does not do so in the presence of a close-in non-example, we demonstrate maintaining S^Di guidance while the S^Dd changes. We can say, "Sit on the chair," and have the observer sit on a chair and not on the couch. We can say, "Pretend to sit on a chair," and the observer may bend in such a way as to resemble sitting on a chair, though no chair (S^Dd) is present. This represents S^Di control in the absence of S^Dd.

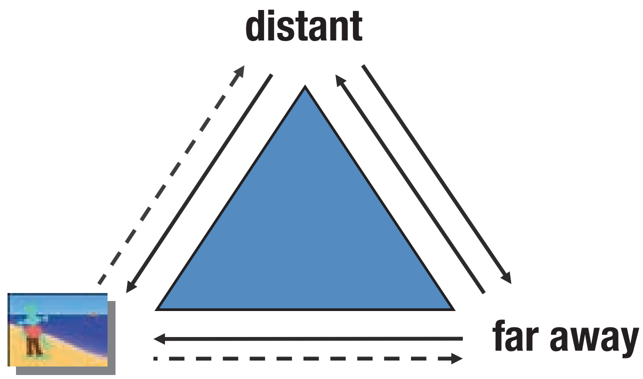

Figure 5. Disjunctive relations established through pairing stimuli. Selecting a stimulus (S^Dd) when another (S^Dd) is presented is reinforced. Reinforcing selecting yet another stimulus (S^Dd) when one of the earlier stimuli is presented can result in a metonymical extension between unpaired stimuli such that these stimuli are treated as if they "go with" or are "the same" (S^Di) as the others.

believes that Y." Once the abstract tact "believe" is established, many other textual stimuli can be substituted in this frame. "Believe" has two critical features that define the S^Di guidance: first, the absence of an event, and second, action taken to affirm existence of the event. To teach a young learner the concept of believing would require a minimal teaching set of six examples and two non-examples (see Figures 6 & 7). The six exemplars are determined by an analysis of the range of varying features found in statements of belief. The two non-examples are determined by the number of critical features such that when one is removed, "believe" is no longer defined (see Sota et al., 2011 and Tiemann & Markle, 1990, for further discussion). By ensuring the greatest range of generic extension for "believe," we ensure the greatest range of autoclitic frame guidance. All of this is part of building a verbal repertoire that is necessary to comprehend text. A range of procedures can expand and extend verbal repertoires where required (see Leon et al. 2011; Sota et al., 2011; for an elaboration, see also Alesi, 1998 and Shahan & Chase, 2002).

THE INVESTIGATIVE REPERTOIRE OF THE READER AND READING COMPREHENSION

Whereas learners from rich verbal backgrounds may need very little direct intervention in terms of the breadth of their verbal repertoire, they may still need to acquire the investigative repertoire that makes verbal repertoire reorganization and extension more likely. Robbins (2004, 2011) has described in some detail a general procedure for establishing such a repertoire. In the case of comprehending text, several distinct repertoires may be required depending on the type of comprehension one is looking to establish. These include literal, inferential, main-idea, and derived-word-meaning comprehension. Each form of comprehending may require a separate investigative repertoire. Since these are described in detail by Sota et al. (2011), a more general overview is presented here.

Changes in an evaluated referent behavior are used to determine if a given written passage is understood. Accordingly, these evaluation criteria (see Sota et al., 2011) require that a reader do more than say the words in the passage or even paraphrase the text. In many cases, learners are asked a series of questions they must answer or, even more likely when it comes to more standardized evaluation, they must choose from among an array of possible answers. They may also have to follow a procedure or demonstrate how the text has changed their repertoire such that they can now perform a task or solve a problem they could not prior to reading the text. Whatever the requirement, they may need to be able to generate supplementary verbal stimulation (Palmer, 1991; Robbins, 2004, 2011; Skinner, 1957, pp. 253 - 292, 1966) that quickly and effectively aligns the S^Di guidance required to meet the contingency requirement to the S^Di actually guiding their behavior. This process involves providing a verbal repertoire whose sequence is conditional on key abstract tacts concerning comprehension type and requirements. We saw an example of one investigative repertoire in our example of Jeffrey's "private activity" at the outset of this article. Jeffrey reads the question, "How did Sam feel when he saw his new bicycle?" He hears the words as he reads. Next, he reads, "sad, happy, funny." But Jeffrey hears the words, "It wants me to find how Sam feels. I'll look back in the passage to see if I can find 'sad,' 'happy,' or 'funny'. No… no… I can't find any of those words in the passage. I'll have to look for clue words that will help me think about how Sam was feeling. Here it says, 'When Sam saw his new bike, he grinned.' Hmmm, 'grinned.' That makes me think Sam was feeling happy, and 'happy' is one of the possible answers. I'll put a mark next to 'happy.'"

One could infer that Jeffrey's thinking led him to the correct answer and, therefore, that his thinking guided his behavior. But why did he think as he did? He read the question and the possible answers. At that point, certain public and private patterns were made more likely than others (e.g., John's patterns). Some-

Believe: S^Dd

ATTRIBUTES OR FEATURES

Critical: S^Di

1. Absence of event
2. Action taken that affirms likelihood of event

Variable:

3. Time frame
   a. future, b. present, c. past
4. Type of event
   a. mechanical, b. natural, c. mythical-supernatural, d. intrapersonal, e. interpersonal, f. social
5. Who takes action
   a. self, b. other person, c. animal
6. Type of action
   a. verbal, b. nonverbal
7. Conditions that suggest event
   a. next step in sequence
   b. mand or other verbal stimulus
   c. outcome of (unobserved) event

Figure 6. Concept analysis that specifies critical (S^Di; abstractional) features and the entire range of examples (S^Dd) that will ensure the desired range of generic extension.

thing occurred while the boys were interacting with the text that provided different S^Di guidance over Jeffrey and John's private "hearing," "seeing," etc. Such S^Di guidance is what may account for both the hearing and the subsequent observed patterns, rather than the private events guiding the observed pattern.

DESIGNING AND BUILDING A PROGRAM TO TEACH LEARNERS HOW TO COMPREHEND TEXT

If this is the case, to understand such guidance, we must investigate the program that established the pattern (Goldiamond, 1974; Goldiamond & Thompson, 1967/2004; Layng, 1995; Layng, Stikeleather, & Twyman, 2006; Layng, Twyman, & Stikeleather, 2004a, 2004b; Moore & Goldiamond, 1964; Twyman, Layng, Stikeleather, & Hobbins, 2004). A program can be defined as a sequence of contingencies with changing criteria that establishes a replicable behavioral outcome. If different programs result in different outcomes, the "cause" of the observed outcome and the associated thinking (and other putative private events) may then reside not in the activities, but in the program. This suggests the study of thinking and other private activity may best be considered the study of programs. Further, if the account presented here has merit, it should be possible to provide programs that result in predictable outcomes and predictable private events. That is, we should be able to teach thinking and how to comprehend text.

Establishing a text comprehension repertoire is complicated by the fact that separate repertoires may be required for each comprehension type and that they must be built into a more general repertoire which allows for the determination of the precise patterns required. Further, the investigative repertoire rests upon an overlap between the writer's and reader's verbal repertoires. All conditions need to be in place.

Over the past five years, a concerted effort has been made to apply this analysis to the research and development of a program to teach typical school-age children how to comprehend written text. That effort resulted in a fifty-lesson online program, Headsprout® *Reading Comprehension*. Such an effort took years of analysis, design, testing, redesign, and retesting until the program produced the patterns required for comprehension and the associated private activities. For descriptions of the research and development process, see Layng, Stikeleather, & Twyman (2006) and Twyman et al. (2004). The research and development effort required a thorough analysis of the comprehension types to be taught, including the instructional/abstractional guidance required, along with the entire range of generic extension needed (see Sota et al., 2011). Determining the stimulus-control topographies required was a critical first step in program design, without which no program could be designed. Once the relations that needed to be established were identified, repertoire overlap considerations needed to be addressed. This included specifying entry decoding levels, the progression of text complexity, the teaching of critical abstract tacts, just-in-time vocabulary support, textually provided repertoire reorganization that made application of investigatory repertoires more successful, the precise investigatory repertoires required, and finally the procedures required for establishing four different comprehension repertoires (see Leon et al., 2011; Sota et al., 2011).

Children's thinking about text was the target of this effort and has been observed, through talk-aloud protocols used in our laboratory, to change as a function of the program. Over 150 children participated in our single-subject control-analysis R&D effort (after Goldiamond & Thompson, 1967/2004). Design protocols required that learners meet a range of pre-established criteria. If learners were not meeting criteria, the program was changed until the criteria were met. Over the course of development, the children's ability to answer complex questions about text greatly improved. An elaboration on this process may be found in Leon et al. (2011).

As of this writing, over 50,000 children are using the product and producing data which will ultimately determine its large-scale effectiveness as measured by standardized reading comprehension assessments. Since learner performance is gathered online for each comprehension type, we are continually analyzing the data and making adjustments in the program. We are greatly encouraged by the data we are seeing. For example, early data from a Chicago elementary school are encouraging. At this school, where student performance has historically been quite low on city-wide assessments, children who completed at least 20 lessons of the reading comprehension program scored over 60% correct on state-wide reading assessments in comparison

MINIMUM EXAMPLE SET

1. They see no one trapped inside a burning building, but everyone is not accounted for; they look inside (believe someone is trapped inside). [1; 2; 3b; 4b; 5b; 6b; 7b]
2. I pray to God for good health (believe in God). [1; 2; 3b; 4c; 5a; 6a; 7c]
3. The car has been sitting for a month, and I get my key to start it (believe the car will start). [1; 2; 3a; 4a; 5a; 6b; 7a]
4. The dog runs back and forth between its empty food bowl and the cupboard, when the door is opened (believes it will get food). [1; 2; 3b; 4e; 5c; 6b; 7a]
5. I look in the mirror, and then I take cold medicine (believe that I will get sick). [1; 2; 3a; 4d; 5a; 6b; 7a]
6. She prepares the grill for the steaks he will bring home (believes that he went to the store). [1; 2; 3c; 4f; 5b; 6a; 7c]

MINIMUM NON-EXAMPLE SET

1. Someone is seen trapped inside a burning building, rescue attempted. [absence of 1]
2. The dog remains laying on a rug looking out the window, ignoring the empty food bowl when the cupboard door is opened. [dog does not look in bowl, absence of 2]

Figure 7. Minimum teaching set required to teach "believe." Brackets [ ] indicate the features varied for for each example and the features absent or each non-example. More examples and non-examples would likely be required. However, based upon an attribute type error pattern analysis the precise examples or non-examples required to achieve the terminal performance can be specified. An entirely different set of six examples and two non-examples would be required to test the concept, that is, the abstract-tact/generic-extension relations.

to the city average of 53%. The previous year those same learners scored far below the city average, with about 37% correct. Further, much to the joy of their teachers, the seven learners who finished all 50 lessons achieved a perfect score on year-end classroom assessments. We are also seeing learners in eleven Tennessee schools making substantial gains on state reading comprehension tests, turning around years of disappointing standardized test score results.

In a major recognition of the efficacy of applying behavioral contingency analysis to solving complex cognitive problems, Headsprout *Reading Comprehension* was selected from a group of over 300 products to receive the Software Industry and Information Association's coveted 2010 CODiE Award in the category of "Best Online Instructional Solution." A more detailed analysis of the program and its development is provided by Leon et al. (2011) and Sota et al. (2011).

CONCLUSION

The interpretation and analysis framework presented here has been used to effectively design and produce a program that changes how children think about text. We do not consider private events to be separate stimuli or behaviors that occur inside the skin and to which a person responds. Instead, we argue that hearing, seeing, smelling, touching, and tasting can be brought under S^{D}i guidance alone, as well as joint S^{D}d/S^{D}i guidance. By recognizing the two forms of guidance, we may be able to provide an interpretation that accounts for private experience without the necessity of postulating a private stimulus to which a person privately responds. By focusing on programs as independent variables, rather than on private events, we have not only been able to produce the changes in learner comprehending we sought, but we may also be helping to provide a comprehensive yet parsimonious approach to the problem of investigating the complex human behavior suggested by "thinking."

REFERENCES

Alessi, G. (1987). Generative strategies and teaching for generalization. *The Analysis of Verbal Behavior*, 5, 15–27.

Bruner, J., Goodnow, J., & Austin, G. (1956). *A study of thinking*. New Brunswick, NJ: Transaction Publishers.

Cohen, T. (2008). *Thinking of others: On the talent for metaphor*. Princeton, NJ: Princeton.

DeRosse, P. & Fields, L. (2010). The contextually controlled, feature-mediated classification of symbols. *Journal of the Experimental of Behavior*, *23*, 225–245.

Donahoe, J. & Palmer, D. (2004). Learning and complex behavior. Richmond, MA: Ledgetop Publishing.

Englemann, S. & Carnine, D. (1991). *Theory of instruction: Principles and application*. Eugene, OR: ADI Press.

Ferster, C. B. & Perrott, M. C. (j). *Behavior Principles*. NY: Appleton-Century-Crofts.

Goldiamond, I. (1962). Perception. In A. J. Bachrach (Ed.), *The experimental foundations of clinical psychology* (pp. 280–340). New York: Basic Books.

Goldiamond, I. (1966). Perception, language, and conceptualization rules. In B. Kleinmuntz (Ed.), *Problem solving* (pp. 183–224). New York: Wiley.

Goldiamond, I. (1974). Toward a constructional approach to social problems: Ethical and constitutional issues raised by applied behavior analysis. *Behaviorism*, *2*, 1–84.

Goldiamond, I. & Dyrud, J. (1966). Reading as operant behavior, J. Money (Ed.) *The disabled reader: Education of the dyslexic child*. Baltimore, MD: Johns Hopkins Press.

Goldiamond, I., & Thompson, D. ([1967] 2004). *The blue books: Goldiamond & Thompson's functional analysis of behavior*, Edited and revised by P. T. Andronis. Cambridge, MA: Cambridge Center for Behavioral Studies.

Layng, T. V. J. (1995). Causation and complexity: Old lessons new crusades. *Journal of Behavior Therapy and Experimental Psychiatry*, 26, 249–258.

Layng, T. V.J. (May 2005). Invited tutorial: The Importance of understanding and "extending" Skinner's extended tacts for behavior analysis applications, the 31st Annual Conference of the Association for Behavior Analysis, Chicago, IL.

Layng, T. V. J. (August 2007). Invited workshop: Complex verbal relations and theory of mind, National Autism Conference, Pennsylvania State University, University Park, PA.

Layng, T. V. J., Stikeleather, G., & Twyman, J. (2006). Scientific formative evaluation:

The role of individual learners in generating and predicting successful educational outcomes. In: Subotnik, R. & Walberg, H. (Eds.) *The scientific basis of educational productivity*. Charlotte, NC: Information Age Publishing.

Layng, T. V. J., Twyman, J. S. & Stikeleather, G. (2004a). Selected for success: How Headsprout Reading Basics™ teaches beginning reading. In: D.J. Moran & R. Malott (Eds.) *Evidence-based educational methods*. St. Louis, MO: Elsevier Science/Academic Press.

Layng, T. V. J., Twyman, J. S. & Stikeleather, G. (2004b). Engineering discovery learning: The contingency adduction of some precursors of textual responding in a beginning reading program. *The Analysis of Verbal Behavior,* 20, 99–109.

Leon, M., Layng, TVJ. & Sota, M. (2011). Thinking through text comprehension III: The programing of verbal and investigative repertoires, *The Behavior Analyst Today*, 12, 21–33.

Markle, S. M. (1978). Teaching conceptual networks. *NSPI Journal*, (February) 4–7.

Markle, S. M. (1981). Training designers to think about thinking. *Journal of Instructional Development,* 4, 24–27.

Markle, S. M. (1991). *Designs for instructional designers*. Seattle, WA: Morningside Press.

Markle, S. M., & Tiemann, P. W. (1969). *Really understanding concepts: Or in frumious pursuit of the jabberwock*. Champaign, IL: Stipes.

Markle, S. M., & Tiemann, P. W. (1974). Some principles of instructional design at higher cognitive levels. In R. Ulrich, T. Stachnik, & J. Mabry (eds.), *Control of human behavior* (Vol. 3, pp. 312–323). Glenview, IL: Scott, Foresman.

Markle, S. M., & Tiemann, P. W. (1980). On beyond the single concept: Conceptual domains. Unpublished manuscript.

Moore, R. & Goldiamond, I. (1964). Errorless establishment of visual discrimination using fading procedures. *Journal of the Experimental Analysis of Behavior*, 7, 269–272.

Palmer, D. (1991). A behavioral interpretation of memory. In L. J. Hayes & P. N. Chase (Eds.) *Dialogues on verbal behavior* (pp. 261–279). Reno, NV: Context Press.

Ray, B. A. & Sidman, M. (1970). Reinforcement schedules and stimulus control. W. N Schoenfeld (Ed.) *The theory of reinforcement schedules* (pp. 187–214). NY: Appleton-Century-Crofts.

Robbins, J. K. (2004). Problem solving, reasoning, and analytical thinking within the Morningside model. In K. Johnson & L. Street (Eds.) *The Morningside model of generative instruction: What it means to leave no child behind* (pp. 126–144). Concord, MA: Cambridge Center for Behavioral Studies.

Robbins, J. K. (2011). Problem solving, reasoning, and analytical thinking in a classroom environment. The Behavior Analyst Today, 12, 42–50.

Saussure, F. ([1916] 1983). Course in general linguistics (trans. Roy Harris). London: Duckworth.

Shahan, T. & Chase, P. N. (2002). Novelty, stimulus control, and operant variability. *The Behavior Analyst*, 25, 175–190.

Sidman, M. (1994). *Equivalence relations and behavior: A research story*. Boston: Author's Cooperative.

Skinner, B. F. (1957). *Verbal behavior.* Englewood Cliffs, NJ: Prentice-Hall.

Skinner, B. F. (1963). Behaviorism at Fifty. *Science*, 140, 951–958.

Skinner, B. F. (1966). An operant analysis of problem solving. In B. Kleinmuntz (Ed.), *Problem solving* (pp. 225–257). New York: Wiley.

Sota, M., Leon, M., & Layng, TVJ. (2011). Thinking through text comprehension III: Analysis of verbal and investigative repertoires, *The Behavior Analyst Today*, 12, 11–20.

Tiemann, P. W., & Markle, S. M. (1990). *Analyzing instructional content: A guide to instruction and evaluation*. Seattle, WA: Morningside Press.

Twyman, J. S., Layng, T. V. J., Stikeleather, G. and Hobbins, K. A. (2004). A non-linear approach to curriculum design: The role of behavior analysis in building an effective reading program. In W. L. Heward et al. (Eds.), *Focus on behavior analysis in education*, Vol. 3. Upper Saddle River, NJ: Merrill/ Prentice-Hall.

Wahlberg, T., & Magliano, J. P. (2004). The ability of high function individuals with autism to comprehend written texts. *Discourse Processes*, 38, 119–144.

Wirth, W. & Chase, P. N. (2002). Stability of functional equivalence and stimulus equivalence: Effects of baseline reversals. *Journal of the Experimental Analysis of Behavior*, 77, 29–47.

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