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Relational Frame Theory and Human Intelligence

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The current paper re-examines the concept of intelligence using Relational Frame Theory (RFT) and suggests a theoretical framework for the analysis of "intelligent" behaviors. We begin by introducing the practices of the standard measurement of intelligence, the intelligence quotient (IQ), and some key features of commonly used IQ tests. We outline a proposed framework, which we suggest provides a rationale for the construction of interventions to raise intelligence quotients as calculated by standardized IQ tests. Specifically, the current paper proposes that training skills in derived relational responding (DRR) by utilizing multiple exemplar training (MET) can accomplish this goal.

Key words: Intelligence, Relational Frame Theory, Multiple Exemplar Training, Derived Relational Responding, Stimulus Equivalence.

Behavior analysts have traditionally rejected hypothetical constructs (rather than private events) such as intelligence (see Skinner, 1974) in their explanations of behavior. In contrast, many psychologists adopt the mainstream view that there exists a common underlying factor that ties all intellectual skills together. Spearman (1904) called this factor 'g', for general intelligence. Behavior analysts have philosophical objections to the concept of intelligence as an extant entity or as a "cause" of behavior, but attempts to provide behavioral analyses of intelligence have been made (e.g., Hayes, Barnes-Holmes, & Roche, 2001; Schlinger, 2003). In addition, behavior analysts often find themselves intervening in applied settings to increase the fluency, sensitivity and flexibility of behaviors assessed in IQ tests (e.g., verbal and computational ability). The current paper is intended to assist those who seek to develop behavioral interventions that reliably raise IQ scores. The development of such interventions would clearly demonstrate the behavior analyst's ability to analyze and affect those behaviors widely referred to as "intelligent" and might even hasten the abandonment of the concept of intelligence as anything other than a mentalistic summary term.

If, as behavior analysts, we forego the explanatory and unifying power of the term "intelligence", then how are we to increase it? Embarking on a program of research to raise IQ is an ambitious endeavor, but the theoretical and technical impetus for it has already been provided by relational frame theory (RFT; Hayes et al., 2001). This theory provides an account of human intelligence from a behavioral perspective. Specifically, RFT decomposes intelligence into its component behaviors and identifies environment-behavior relations that establish, maintain and sensitize those behaviors. In highlighting these environmental contingencies, shared features of the relevant histories emerge that suggest opportunities to

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intervene in new and potentially powerful ways to enhance cognitive performance.

The current paper will outline the RFT account of human intelligence and provide recommendations for the development of interventions to raise IQ based on preliminary research. In the first section of this paper, we will introduce the core components of RFT. This will provide the analytic tools that we will use to decompose intelligence. In the second part of this paper, we deconstruct performance on some well-known IQ tests to demonstrate the utility of these relational frame concepts. We will then review some current research that demonstrates that relational responses can be enhanced in a variety of important ways, before we conclude with specific recommendations for those who wish to develop interventions to raise IQ.

Relational Frame Theory

The core idea behind Relational Frame Theory was developed by Steven Hayes and Aaron Brownstein and further refined by Linda Hayes in the 1980s (Hayes, 1991; Hayes & Brownstein, 1985; Hayes & Hayes, 1989). RFT reoriented Skinner's (1957) analysis of verbal behavior by following out the implications of focusing on the behavior of the listener in a verbal interaction (see also Barnes-Holmes, Barnes-Holmes, & Cullinan, 2000). In attempting to characterize the listener's understanding of verbal statements, it was clear that direct stimulus control was not sufficient. That is, a history of reinforced responding in the presence of each word was not possible to provide in the length of time in which language is acquired, especially when one considers the variety of responses occasioned by a single word (e.g., chest) in the many contexts within which it may be presented (e.g., treasure chest, chestnut, chest pain). Hayes and colleagues suggested that a listener's understanding required derived relational responding, predictable untrained responses that occur due to relationships between known and novel stimuli regulated by arbitrary contextual cues, and that these responses in turn fundamentally altered behavioral ideas about the core properties of the verbal actions of speakers.

Researchers (Sidman, 1971; Sidman & Tailby, 1982) had already demonstrated that predictable untrained responses might be occasioned by previously neutral stimuli if those stimuli were included in a very particular history. They termed the effect stimulus equivalence. In a typical training scenario, participants were trained on a series of conditional discriminations. The first conditional discrimination involved teaching the subject to choose between two comparison stimuli, labeled for convenience as B1 and B2, conditional upon the presentation of A1 or A2, respectively, as a sample. The second conditional discrimination task involved choosing between two further comparisons, C1 and C2, conditional upon the presentation of B1 or B2, respectively, as a sample. In effect, subjects were taught to choose B1 given A1 and C1 given B1 (A1-B1-C1) and to choose B2 given A2 and C2 given B2 (A2-B2-C2). When provided with this (linear) training protocol, most verbally-able subjects will match each stimulus with itself in the absence of reinforcement. For instance, when given A1 a sample, and A1 and B1 as comparisons, verbally-able subjects will choose the A1 comparison. This behavioral outcome is referred to as *reflexivity*. Furthermore, subjects will derive symmetrical relations between the stimuli without feedback or reinforcement. *Symmetry* involves the spontaneous transfer of stimulus control from the sample stimulus to the comparison stimulus in a matching-to-sample preparation. Thus, given the above training, a subject will be able to pick A1 from an array when given B1 as a sample, and B1 from an array when given C1 as a sample. Finally, subjects will display *transitivity* in the absence of reinforcement. This refers to the spontaneous combining of trained relations and the emergence of stimulus control for comparison stimuli not directly associated with the original sample stimulus. For instance, if a subject is trained to pick B1 from an array given A1 as a sample, and C1 given B1, the stimulus C1 will now be chosen given A1 (i.e., the response functions of B1 have transferred to A1). When all three features have been observed a stimulus equivalence relation is said to have formed among the relata (see Fields, Adams,

& Verhave, 1993; Fields, Adams, Verhave, & Newman, 1990; Sidman, 1971, 1986).

Relational Frame Theory conceptualized equivalence relations as just one possible relation that might occur between stimuli and provided a somewhat different nomenclature. These terms were intended to enhance the explanatory power of RFT by employing the same terms for all relationships. According to RFT, derived relations involve the properties of *mutual entailment*, *combinatorial entailment*, and the *transformation of function*.

Mutual entailment

If a stimulus A is related to (i.e., same as, bigger than, smaller than, on top of) another stimulus B, then a derived relation between B and A is mutually entailed. The type of relation mutually entailed depends upon the nature of the relation between A and B (B is the same as, smaller than, bigger than, beneath A; Hayes, 1994). For instance, if the stimulus A bears an *equivalence* or "coordination" relation to the stimulus B ("A is the *same as* B"), then the relation "B is the *same as* A" is mutually entailed. However, if the stimulus A bears a relation of *comparison* to the stimulus B (e.g., A is *more than* B), then the relation "B is *less than* A" is mutually entailed.

Combinatorial entailment

If a stimulus A is related to B, and B bears a further relation to C, then a relation between A and C is combinatorially entailed. The nature of the combinatorially entailed relation depends on the nature of the trained relations. For example, if "A is *more than* B" and "B is *more than* C", then a "*more than*" relation between A and C is derived by combinatorial entailment (i.e., A is *more than* C) and a "*less than*" relation is entailed between C and A (i.e., C is *less than* A).

Transformation of function

If a stimulus A is related to another stimulus B, and A acquires a psychological function, then in the appropriate context the stimulus functions of B will be transformed in accordance with the A-B relation. For example, if "A is *more than* B", and A elicits fear, then B will produce less fear than A.

Relational Frame Theory identifies responding that demonstrates mutual, combinatorial entailment and transformation of function as relational framing. RFT suggests that the ability to respond relationally is itself an operant. This sets the theory apart from Sidman's view of derived relational responding as a basic stimulus function (e.g., Sidman, 2000; see Hayes & Barnes, 1997). In simple terms, RFT suggests that the ability to derive relations is itself established by caregivers at an early stage, across multiple exemplars, often without the caregiver even being aware. At a later stage, familiar relations (e.g., equivalence) can be derived using novel stimuli, but the skill itself is far from novel. For example, suppose a mother tells her child that a certain piece of fruit is an 'orange' and reinforces appropriate echoing of that word in the presence of the object. This practice establishes the object-word relation. Now, suppose the mother also asks the child to "show me the orange" and reinforces the appropriate orienting response towards the object (e.g., by pointing). This establishes the word-object relation. Across thousands of such exemplars with different objects, the mother is wittingly or unwittingly teaching the child that all word-object and object-word relations are reversible (Hayes, Fox, et al., 2001, p. 26-27). Verbal ability, therefore, involves using and responding to words whose meanings constitute responding in accordance with *equivalence* relations (Barnes, McCullagh & Keenan, 1990; Berens & Hayes 2007, Devany, Hayes, & Nelson, 1986, Hayes, Fox et al., 2001).

One important feature of RFT in the current context is its suggestion that a small variety of these arbitrary relations (e.g., *same, opposite, more-than, less-than*) when combined may be sufficient to yield the full gamut of cognitive skills (e.g., deductive reasoning, inductive reasoning, analogy, etc.) associated with high intelligence. The effective use of the RFT approach in applied settings will require research that will identify the nature and number of multiple exemplars that are needed to establish particular repertoires of relational responding. This research will need to functionally map the development of specific repertoires of relational skills in terms of their impact on specific aspects of cognitive abilities.

In effect, such an endeavor would allow behavior analysts to speak more directly than ever before to the concept of intelligence as interpreted and measured by widely employed psychometric tests. To illustrate this point, the following section considers some specific dimensions of intelligence as traditionally conceived by intelligence tests and illustrates how RFT provides a conceptual framework for the functional analysis of the relevant behavioral skills.

Intelligence as a Trait

A thorough consideration of intelligence and its measurement lies beyond the scope of the current manuscript. The cursory introduction provided here will inevitably leave many issues simplified, but we will specify the meaning of "intelligence" that we intend to employ. Lohman (2001) usefully employed Mayr's (1982) distinction between population thinking and essentialist thinking in biology to distinguish between two types of thinking in psychology. Population thinking seeks to quantify variation and diversity and population-level patterns, whereas essentialist thinking seeks to identify functional relationships and properties. Population thinking characterizes population genetics and psychometry, essentialist thinking guides the experimental biologist or psychologist. As the quintessential experimental psychologists, behavior analysts typically engage in essentialist thinking (though only in this very particular sense of "essentialist"). That is, we manipulate potential independent variables (e.g., by providing reinforcers) to change dependent variables (e.g., to increase behavior). The concept of intelligence often employed by psychometricians is a population-level concept that is often misunderstood as an essential property of the individual or his/her behavioral history by both psychometricians and experimental psychologists.

Traditionally, intelligence is viewed as an invariant trait that is more or less normally distributed across the population. A high value on this trait predicts success in employment and academia, and low values identify learning and developmental disabilities. The idea that test scores are constrained by stable innate abilities is supported by the fact that quotient scores change little across the lifetime. For instance, several studies have been conducted that provide evidence for the concurrent validity and reliability of the Wechsler Intelligence Scale for Children-Revised (WISC-R; Wechsler, 1992). These studies provide strong evidence for the longitudinal stability of global IQ estimates derived from the Wechsler scales (Sattler, 1988). Other studies have shown acceptable levels of predictive validity for black and white children (Hartlage & Steele, 1977, Juliano, Haddad & Carroll, 1988, Reschly & Reschly, 1979) and comparable validity among males and females (Reynolds, Gutkin, Dappen, & Wright, 1979). In effect, it is generally accepted among psychometricians that the construct of IQ is relatively stable across a lifetime and across the population. In effect, the stability of intelligence quotient scores (as opposed to raw scores, which change significantly across the lifespan) is used as evidence that the underlying trait is itself stable (Gardner, 1993). Given these traditional views, it would seem that intelligence quotients cannot in principle be raised (see Gardner, 1993, for criticisms of this approach).

The trait concept of intelligence is, however, a population-level construct. It does not measure any single feature of a person or their environment. Rather, it allows relatively useful predictions to be made about that person, all other things being equal. Intelligence as abstracted from IQ tests is not dependent on education, gender or test administrations, because psychometric tests are constructed carefully to ensure that these factors are, on average, controlled. For example, raw IQ scores typically rise by a considerable amount due to education and biological changes across a lifetime and measurably so from year to year, and even from quarter to quarter. Psychometricians compensate for these disruptive effects on the stability and distribution of IQ scores by adjusting for chronological age when calculating IQ scores. Even with these adjustments, there has been a marked increase in IQ test performance during the 20th century, which is termed the Flynn effect (Flynn, 1998, 2007). IQ tests are therefore re-designed and re-interpreted in order to control for these changes. These practices may seem suspect to the behavior analyst, but it makes sense from a population perspective to adjust IQ tests to better measure a 'known' construct with known statistical properties.

The statistically generated normal distribution of IQ test scores is employed to provide each individual taking an IQ test with a score relative to the general population or a relevant group of peers. This relative score is calculated based on demographic characteristics such as age and gender. These factors are used to alter the score proportionate to their known impact on the raw test score, which changes as a function of these variables. In effect, the relative rarity of rises in IQ is attributable to the fact that IQ scores are corrected statistically by precisely that factor required to keep scores constant given the known effects on scores of increasing age and practice. Thus, a very large improvement in raw IQ score would be required in order for a significant change in IQ (e.g., one standard deviation) to be recorded. With the foregoing in mind, a behavioral approach to raising IQ scores may not appear to be feasible, especially when we consider that there is no internal "intelligence" to be enhanced. On the contrary, we contend that interventions are required that will improve specific cognitive skills, sufficient to move raw IQ test or subtest scores (i.e., before normalization techniques are applied) *more than they typically do* in a given period of time.

Previous behavior-analytic studies have included IQ test measures as part of interventions for severe disability. For example, Lovaas (1987) reported IQ gains as large as 30 points from the outset of a three-year intensive ABA intervention for autism. Just under half of the children that took part in that study appeared to "recover" from autism, in that they were not noticeably different from normally functioning children after three years (Reed, Osbourne, & Corness, 2005). Unconvinced of the reliability of the reported IQ rises, Reed et al. (2005) raised concerns regarding the internal and external validity of the study (see also Connor, 1998; Gresham & MacMillan, 1997). Magiati and Howlin (2001) also criticized the study on the grounds that different IQ tests were often used at baseline and at follow up, thereby reducing the reliability of the measurement. In addition, these researchers pointed to a series of serious methodological flaws regarding subject selection, treatment condition assignment, differing treatment periods across the experimental and control groups, and the already high-functioning intellectual ability of the treatment group. Nevertheless, Sallows, and Graupner (2005) also recorded significant IQ rises in a more recent replication of the Lovaas (1987) study.

In a further study, Smith, Eikeseth, Klevstrand, and Lovaas (1997) studied IQ, expressive speech and adaptive behavior improvements among severely mentally retarded children with autistic features during an ABA intervention. Children exposed to the treatment condition displayed a higher mean IQ at follow-up and evinced more expressive speech than did those in the comparison group. Behavioral problems diminished in both groups. This and the other studies outlined, while showing promise that behavioral interventions may lead to IQ rises, were concerned with IQ only as one part of a larger range of dependent measures in wide-ranging and multifaceted studies typically involving interventions to improve the autistic condition and/or other pervasive developmental difficulties. What is required, however, is a focused approach to understanding what we mean by intelligence from a behavioral perspective, and a targeted program of research and intervention to illustrate that intellectual skills can be brought under operant control.

Relational Responding and Psychometric Measures of Intelligence

The position that focusing on relational responding may enhance behavioral interventions is supported by a series of recent studies that have demonstrated that the ability to respond relationally in novel contexts predicts performance on IQ measures. O'Hora, Pelaez, and Barnes-Holmes (2005) compared performance on a complex relational task involving pre-training and testing for *before/after* and *same/different* relations, a test for instructional control and a test for generalization of instructional control using novel stimuli to performance on three subtests of WAIS III (*Vocabulary, Arithmetic,* and *Digit-symbol coding*). Participants who successfully completed the complex relational task (n=31) performed significantly better on the *Vocabulary* and *Arithmetic* subtests than those subjects (n=44) who failed to do so. No significant differences in relational task performances were found between groups for the *Digit-symbol coding* subtest. Significant correlations were observed between performance in training and testing for *before/after* and Vocabulary and Arithmetic. In a later study, O'Hora et al (2008) found significant correlations between performance in training and testing for *before/after* relational responding and Full Scale, Verbal and Performance IQ. Relational responding correlations loaded particularly highly on the Verbal Comprehension (r = .403) and Perceptual Organization (r = .409) factors of the WAIS-III. O'Toole and Barnes-Holmes (2009) employed the Implicit Relational Assessment Procedure (IRAP) to test *before/after* and *same/different* relations and found that performance on the relational tasks that required reversing known relations correlated with IQ as measured by the Kaufman Brief Intelligence Test (*r(before/after)* = .38, *r(same/different)* = .35). Finally Gore, Barnes-Holmes, and Murphy (2010) found significant correlations between performance on a test for deictic (perspective taking) relational responding and Full Scale (r = .43), Verbal (r = .45) and Performance IQ (r = .45; p.12) as measured by the Wechsler Abbreviated Scale of Intelligence (WASI; Psychological Corporation, 1999).

In addition to the foregoing correlations, a variety of other findings support the position that relational responding and cognitive (especially verbal) abilities may be functionally related. First, common patterns of brain activation accompany successful completion of semantic processing tasks and demonstration of transitive and equivalence relations (Barnes-Holmes et al, 2005; Barnes-Holmes et al., 2005; Dickins et al., 2000; but see Schlund, Cataldo, & Hoehn-Saric, 2008). In a longitudinal study, Lipkens, S.C. Hayes and L.J. Hayes (1993) found that the ability to derive relations fluently occurs at the same time as the "language explosion". In the authors' words; "…by 23 months the child would mutually relate novel names and objects based on a relation of difference with a known object." Studies by Devany, Hayes, and Nelson (1986), and Barnes, McCullagh, and Keenan (1990), demonstrated that language-disabled children did not derive equivalence relations under certain conditions. Dugdale and Lowe (1990) and Hayes (1992) have argued that despite the capacity of most vertebrate species to acquire the basic trained relations, only verbally-able human subjects display the spontaneous emergence of novel relations satisfying criteria for equivalence, with a few possible exceptions (e.g., C. R. Kastak & Schusterman, 2002; C. R. Kastak, Schusterman, & D. Kastak, 2001; D. Kastak & Schusterman, 1994).

Deconstructing Intelligence

In order to enhance performance on psychometric tests of IQ, it is necessary to deconstruct IQ tests in an attempt to identify the generalized behaviors that these tests measure. In the following section, we discuss a variety of items and subscales of common IQ tests in terms of the particular relational responses that these tests may occasion. This analysis is necessarily preliminary, but it is intended to provide a starting point for the development of relational responding interventions. We will organize this section according to the relational frames or combinations of frames that these items and subscales seem to require.

Coordination

Coordination relations are relations of sameness. Some examples of items in the *Vocabulary* subtest of the Wechsler Intelligence Scale for Children, 3rd edition, UK (WISC-III UK) include questions that appear to assess *prima facie* relational skills. Specifically, the WISC-III UK contains questions like, "What is an umbrella?" and "What does brave mean?". While these items test for object-word coordination relations and word-word equivalence relations, respectively, their intention is to examine the extent of a person's vocabulary rather than the culturally specific arrangements of language categories. Questions such as, "What does dilatory mean?" or "What does imminent mean?" are further examples of word-word relations, while "What does aberration mean?", "What is an amendment?", and "What is an affliction?" are further examples of probes for word-object equivalence relations. From the RFT perspective a vocabulary test, while relatively rudimentary as a test of foundational language skills, likely makes a satisfactory approximation of a test for relational skill because the two skills should correlate very highly for a verbally-able individual.

The *Picture Concepts* subtest on the Wechsler Intelligence Scale for Children fourth edition, UK (WISC-IV^{UK}), while it is not classified by the test manufacturers as a verbal test, is a test for frames of *coordination*. Specifically, in this subtest, a child is presented with two or three rows of pictures, and must choose one picture from each row to form a group with a common characteristic (see Wechsler, 2004). For example, in one row a child will see a piece of cheese, a butterfly, flowers and weighing scales. In the next row, a child will see a map, a palette of paint, a lamp and a paintbrush. In the third row, the child can see a newspaper, an ice-cream cone, a different bunch of flowers and a postage stamp emblazoned with a flower. The child must choose the scales, the map and the newspaper as having common characteristics (i.e., because one can "read" all of these items to gain information). Of course, the formal features of these stimulus items are dissimilar, requiring that the commonalities be based on the participation of the relevant stimuli in common derived frames of coordination, rather than on their formal features. Thus, the verbal skills assessed in this task are overarching skills applied across many domains, some of which may be traditionally referred to as verbal, others as spatial, and others as computational.

The CAT is a group-administered test intended to provide a set of measures of an individual's ability to use and manipulate abstract and symbolic relationships (Thorndike, Hagen, & France, 1986). Thorndike et al. (1986) have explicitly described the test items as providing an index of "relational thinking". They define relational thinking as the "perceiving of relationships among abstract elements in a variety of media and settings". The CAT is composed of three batteries: a verbal, a quantitative and a nonverbal battery.

The verbal battery of the CAT is designed to appraise "relational thinking" when the relationships are formed in verbal terms. This test is clearly composed of probes for equivalence relations among stimuli. An example of one test item involves presenting a child with a word, such as "change", in bold print, and asking the child to pick the word that has the same meaning from a further list of words, such as; "leave, loose, coins, fasten, noise". Another test in this section presents the student with the following incomplete statement; "Jack, Jim and Charles are _______." The child must choose the best answer from the following list: "sisters, daughters, mothers, brothers, grandmothers". This item clearly requires the child to tact the equivalence relation that obtains between the stimuli presented in the prompt. In another subtest in the verbal battery, a child is presented with a list of words which they are informed are alike in some way. For example, they may be presented with; "gaze, glance, stare" and asked to choose which of the following words belongs in the foregoing list; "wonder, dream, notice, study, look". This probe for effective knowledge of synonyms would appear to represent a clear example of a test for stimulus equivalence among verbal stimuli.

Opposition

Opposition relations are often also involved in tasks that depend on coordination relations. The AH4, developed by Heim, Watts and Simmonds, is designed as a group test of general intelligence for use with an adult population (Heim, Watts, & Simmonds, 1968, 1975). In the AH4, there are many examples of relational skill tests. Probes for derived relations of opposite can be seen in questions like; "Up means the opposite of; 1) short, 2) small, 3) low, 4) down, 5) young", and; "Near means the opposite of; 1) close, 2) road, 3) speed, 4) far, 5) distance". An example of a synonym test item that requires responding to equivalence relations between words is; "Ill means the same as; 1) health, 2) fever, 3) dirty, 4) mumps, 5) sick". A further example is; "Portion means the same as; 1) some, 2) whole, 3) part, 4) any, 5) cake".

Comparison

Comparison relations are required to respond to a novel stimulus in terms of its directional displacement from a known stimulus (e.g., more than/less than, above, below). Mathematical skills as assessed in standard IQ tests also represent what appears to be an index of the ability to derive and apply abstract relations. For example, in the *Arithmetic* subtest of the WISC-III^{UK}, a child is posed with the following problem; "Joseph has 5 cakes. He gives 1 to Sam and 1 to Alice. How many does Sam have left?" Another problem is as follows; "Phil earned £36; he was paid £4 an hour. How many hours did he work?" Questions like these are highly abstract and novel, but from a RFT perspective the skills involved in responding correctly to these test items may not be so novel. Specifically, answering an infinite range of such questions correctly requires a highly topographically flexible repertoire of relational skills. The infinite variety of possible questions of this kind precludes the possibility of learning each one individually (i.e., producing a relationally inflexible topographically constrained response to pre-set questions). For instance, a child who responds correctly to the questions above should also be able to respond correctly if Joseph gave an additional cake to Michael or if Phil earned £5 an hour. The reason for this is that with mathematical skills, a teacher does not only teach computation by rote, but also teaches the relative relations between numbers such that a child should be able to respond to the relations 5-2 and 8-5 as being the same (i.e., 3). For instance, if presented with the numbers; "1, 5, 9, 13, 17 …", most verbally-able adults would have little trouble correctly providing the next number in the series (i.e., 21). This is a relational problem and is solved by responding to the single relation that consistently obtains between subsequent items in the series and applying that relation arbitrarily to the last number in the series. In the above case, the relation between subsequent items in the series might be called "*plus 4*" (see Y. Barnes-Holmes et al., 2001, p. 162). Thus, the skill that is being taught has little to do with the fact that "17+4=21", but everything to do with the ability to generalize the skill of "*adding 4*" to any given arbitrary number or sequence of numbers.

Complex mathematical problems often involve increasingly more subtle contextual control over DRR. For instance, in a problem involving calculating the distance travelled by a train between two points in a given time under a range of different conditions (e.g., varying speed) there may be multiple sources of contextual control that come together to produce the correct response. More specifically, the problem may not be correctly solved by bringing relational responding under the control of one specific contextual cue for responding in accordance with an addition or a multiplication relation. Rather the solution may involve responding to both relations simultaneously or in a specific sequence. The history of exemplar training required to produce these highly subtle forms of contextual control over relational responding needs to be considerably extended. Indeed the ability to solve such problems at a high level of fluency may not be routinely established for many verbally able adults by our educational systems.

Temporal

Responding to events in terms of their temporal displacement constitutes responding in accordance with temporal relations (e.g., before/after). A temporal relation can be understood as a type of comparison relation. Tests for temporal relations can be found in the *Information* subtest. This subtest contains questions such as; "Which month comes next after April?" and "What is the day that comes after Friday?" Further examples of temporal relations can be seen in the *Picture Arrangement* subtest, in which a child is presented with several cards that depict a short story in a comic-strip format. The task requires that the child arrange the cards so that they tell a story that makes sense in real time. For example, one must take money out of her wallet before she can put it in the vending machine, one must put money in a vending machine before she can choose her chocolate bar. Finally, one must choose the chocolate bar before the vending machine will dispense it (see Wechsler, 1992). If a child does not have a previously established history of flexible and richly contextually controlled temporal responding, they will not be able to complete these tasks using novel stimuli.

Hierarchical

Hierarchical relations are those that occur between categories and their members. They are similar to comparison relations. Examples of the relation of hierarchy, or what we might call "*containment*" can be found in the questions; "What is water made of?" and "What is the main material used to make glass?" These test items require participants to respond to the arrangement of substances in relation to each other in the context of water. So for example, the answer "molecules" is insufficient because all objects are ultimately made of molecules. Instead, what is required is to organize the levels of object structure so that the next lowest level of object structure beneath water as a chemical compound is named correctly. This requires responding to the materials inherent in water in the correct hierarchical order.

Combinations of Relations

The Similarities subtest of the WISC- III^{UK} presents examples of relational tests for frames of coordination (or stimulus equivalence) that are often quite abstracted (i.e., arbitrarily applicable). Specifically, one question in this subtest is; "In what way are a piano and a guitar alike?" This question is clearly analogical. That is, the question involves responding to one stimulus item as equivalent to another in terms of a further set of topographical or arbitrary features. In this example, that further set of features happens to be topographical (i.e., both are musical instruments with steel strings). In answering correctly, the individual is responding to the common classification of both stimuli as musical instruments. In other words, the stimuli share a common *equivalence* relation with the term "musical instrument". In fact they are even defined as such. Thus, the task is examining two very frequently encountered verbal relations and the subject's ability to respond to these two relations as involving a common member. Responding in this way requires a rich history of responding to the test items in a variety of different contexts including both the relationships among the stimuli and the functions of the stimuli.

Further examples of simple analogical tasks can be seen in the WISC-III^{UK} within the *Similarities* subtest. For instance, in that subtest the question is asked, "In what way are a painting and statue alike? A painting and a statue are both members of equivalence relations with the term "art". In other words, they bear the same relationship to art; this is what they have in common. Another question asks; "In what way are rubber and paper the same?" In this example, the commonality is that both rubber and paper are *manufactured from* trees. This example is based on a more abstracted commonality among stimulus items than seen in simpler analogies. This task requires that a child can identify a commonality between items that would not usually be thought of as similar. Indeed, in one test item commonalities must be discriminated between items normally responded to as the opposite of each other (i.e., "How are anger and sadness the same? and "In what ways are first and last alike?").

The quantitative battery on the CAT is designed to appraise a child's perception of relationships among concepts. From a RFT perspective, these tasks assess more than and less than relations between numerical stimuli, which are themselves products of relational responding to pairs of items. For example, the child is presented with two columns of items and asked to mark A if Column I is more than Column II, to mark B if Column I is less than Column II and to mark C if Column I is equal to Column II. In this exercise, Column I might consist of something like; "25% of 200" and Column II might consist of "50% of 100". In this case, calculating a percentage requires the child to respond analogically to each stimulus pair. More specifically, they must respond to the relation between the numbers presented in the first stimulus pair (e.g., 25 and 200) in terms of another stimulus relation not present. That is, they must respond to the relation between 25 and 100 (i.e., the first relational response required in order to respond correctly to percentage problems; in this case the former is one quarter of the later) and apply this relation arbitrarily to 200. When one quarter of 200 is responded to as 50, the child has identified that the relation between 25 and 100 *is the same as* the relation between 50 and 200. Thus, the first behavioral product is 50. The second behavioral product (50% of 100) can now be calculated in the same way (the answer is also 50). The relation that obtains between these items presented in a given sequence (i.e., equivalence) can now be tacted by a student exposed to a sufficient number of more than, less than, and equivalence exemplar tasks.

In another version of the problem, Column I might consist of the "Cost of ten lemons at 3 for 13p" and Column II might consist of the "Cost of ten lemons at 4 for 15p". Thus, the child is being asked again to tact the relationships among the complex verbal stimuli, which essentially produce the same behavioral product (e.g., variously described amounts of money have equal reinforcing value) or share the same behavioral functions despite obvious topographical differences.

Finally, the non-verbal battery of the CAT tests identification of, and flexibility in manipulating relationships expressed as figural symbols or patterns. For example, in one item the student is presented with a small white circle on top of a small white circle, a small white diamond on top of a small white diamond and a small white triangle on top of a small white triangle. The child is then asked to choose a drawing that goes with the first three from a sample of; a large white diamond, a small white semi-circle on top of a small white semi-circle, a large light shaded rectangle, a small white sideways triangle on top of a black sideways triangle and a large white semi-circle beside a large white semi-circle, where the semi-circles are facing in opposite directions.

From a RFT perspective, the foregoing is a test for analogical reasoning. According to RFT, an analogy is established when the trained or derived relations in one network of relations are placed in a frame of *coordination* with the trained or derived relations in another network of relations (Stewart, Barnes-Holmes, Hayes, & Lipkens, 2001). Thus, the foregoing test item assesses a subject's ability to tact the common relation between sets of relations. In the above example, the relations characterized by the geometric shape pairs are all of *equivalence* (i.e., the shapes appearing as pairs are all the *same as* each other). However, in the comparison set of stimuli, only one of these pairs contains geometric shapes that are the *same as* each other (i.e., a small white semi-circle on top of a small white semi-circle). Thus, the subject taking the test must choose which of the comparison pairs is characterized by the same stimulus relation (e.g., *same, opposite*, etc.) as that characterized by all the stimulus pairs in the sample set. RFT views this sort of analogical responding as a higher-order level of relational ability and crucial to complex problem solving.

Examples of test items that require responding to relations between relations (i.e., analogy) can be seen in questions such as; "Army is to navy as soldier is to; 1) airman, 2) sea, 3) service, 4) sailor, 5) uniform". Finally, clear examples of tests for *larger than/smaller than*, *before/after*, *if/then* relations and number series problems can be seen in questions such as; "If a castle is bigger than a cottage, write down the second number of these figures: 1, 2, 3, 4, 5, 6, 7, 8, 9. "If it is not, write down the sixth." In these test items a child is asked to tact the increasingly complex and abstract relations among stimuli and among relations between relations.

Developing Relational Skills Interventions to Raise IQ.

The unique contribution of RFT to understanding intellectual development stems from the fact that it suggests improvements for educational technologies that are traditionally concerned with content delivery rather than behavioral process. In the previous section, we deconstructed performance on IQ test items in order to highlight component relational repertoires that one might seek to enhance in order to improve intellectual ability. Because relational framing is an operant process, multiple exemplar training (MET) is the primary method by which to expand verbal relations and to enhance their sensitivity to contextual control. Put simply, MET involves training children in core relational skills, such as deriving relations in accordance with a wide variety of relational frames and across a very large number of exemplars. Once such component relational skills are established and sufficiently generalized across novel stimulus sets, a child should be able to respond appropriately to an almost infinite number of other similar relational tasks. Consequently, their ability to respond appropriately to the relational tasks presented in common IQ tests should be enhanced.

Recently, a number of studies have demonstrated that MET interventions can be employed to enhance repertoires of derived relational responding. For example, Y. Barnes-Holmes, D. Barnes-Holmes, and Roche (2001) found that explicit exemplar training is a reliable means by which to facilitate generalization of a relational skill in accordance with *symmetry*. In this study, the authors employed sixteen children (aged 4-5) across four experiments (i.e., 4 children each experiment). In these experiments, participants were first trained to name two actions and two objects by demonstrating listening, echoic, and tacting behaviors. Across the four experiments, participants were exposed to a variety of different training methods (e.g., naming, MET) using the previously named actions and objects before being exposed to a test for derived object-action symmetry relations. Explicit symmetry training was the MET intervention employed in this case. Across the four experiments, explicit symmetry training was by far the most effective training method employed and 13 out of 16 participants failed to show derived object-action (Experiments 1-3) or action-object (Experiment 4) symmetry until they received it. This robust effect was replicated by Y. Barnes-Holmes, D. Barnes-Holmes, Roche, and Smeets (2001) and extended by Gomez, Lopez, Martin, Y. Barnes-Holmes, & D. Barnes-Holmes (2007). Finally, Luciano, Becerra, and Valverde (2007) demonstrated the efficacy of a MET intervention for derived symmetry in a 15 month-old infant.

In a further study, (Y. Barnes-Holmes, D. Barnes-Holmes, & Smeets, 2004), children were trained to relate stimuli in accordance with relations of opposition and then to derive novel *same* and *opposite* relations across several sets (e.g., the opposite of an opposite is a same, but the opposite of an opposite of an opposite is an opposite). In effect, participants were presented with a sample derived relations problem and then re-presented with the same problem involving different stimuli. Initially, all three participants failed to pass baseline tests for specific patterns of relational responding in accordance with opposite relations. A MET intervention was employed to successfully develop the performance. Generalization tests also demonstrated that the relational responding generalized to novel stimuli and experimenters. Y. Barnes-Holmes, D. Barnes-Holmes, Smeets, Strand, & Friman, (2004) demonstrated that repertoires of *more-than* and *less-than* relational responding, could be established using MET, when these skills were absent in young children.

Berens and Hayes (2007) systematically tested the impact of each of several phases of MET on the derivation of the entire frame of comparison. Their participants included four female participants, ages 4-5 years old, all of whom could not perform a series of problem solving tasks involving arbitrary more-than and less-than relations. Each child was first administered the Vineland Adaptive Behavior Scale to get a general picture of their individual ability levels. Stimuli included three sets of uniquely colored paper pictures. Each session began with the experimenter telling the child that they were going to play a game and that the child's job was to pick the picture that would buy them the *most* candy. Trials consisted of linear relations (A >B or A<B) and mixed non-linear trials (A>B>C and A<B and C<B). Responses were followed by contingent feedback. Reaching accuracy goals were reinforced with prizes chosen by participants' at the beginning of each session when the goals were set. Non-contingent reinforcement was provided during baseline and probe conditions due to the considerable length of these conditions. A multiple probe across stimulus sets was employed to evaluate the degree to

which reinforced responding with the targeted stimulus set generalized to untrained stimulus sets. A multiple baseline across participants was employed to control for maturation and extra-experimental conditions. The study found that reinforced MET facilitated the development of arbitrary comparative relations, and that these skills generalized across stimuli and trial types.

In light of the foregoing evidence, Cassidy, Roche, and Hayes (in press) investigated the effects of two MET interventions on IQ scores of young children. In the first experiment, 4 children were exposed to multiple exemplar training in stimulus equivalence and *same/opposite* and *more than/less than* relational responding across several sessions and weeks. Children's scores on the Wechsler Intelligence Scale for Children (WISC-III^{UK}) measures were taken at baseline, following stimulus equivalence training, and again following training on multiple relations. Matched against a no-treatment control group, the children showed significant improvements in full scale IQ following stimulus equivalence training, and an even greater improvement following training on multiple relations. In the second experiment, a further 8 children were exposed to an improved multiple exemplar-based relational frame training intervention. For 7 of the 8 children, full scale IQ as measured by the WISC-IV^{UK}, rose by at least one standard deviation and the improvement was statistically significant at the group level. This study, although preliminary, provides direct support for the position that MET interventions directed at relational responding repertoires can increase measured IQ (see also Cassidy, 2008 for empirical evidence).

Conclusion

If there is a functional relationship between DRR and language skills, as suggested here, an improvement in DRR repertoires may well produce a measurable change in language ability (i.e., acquisition rates, fluency, and extent of vocabulary). This is a remarkably exciting possibility for behavior analysts given the already healthy state of the research on multiple exemplar technology. As suggested by the preliminary findings of Cassidy et al. (in press), these improvements in relational ability may also lead to modest, or even dramatic rises in overall IQ scores, or on specific dimensions or subtests of IQ, as argued in this paper. Thus, one true value of research into derived relational responding will be found in the educational programs that might be established to produce changes in the intellectual abilities of children.

Of course, over time the relative impact of relational skills levels on overall IQ scores may emerge. It is likely that other factors, such as attentional skills, the absence of sensory deficits and other diagnosed behavioral and emotional difficulties, are likely to also play an important role. Thus, the effects of relational interventions may not be linear or easily predictable without understanding their relationship to a whole host of other important educational, social, biological, and psychological variables that have been studied by behavior analysts for the past half-century. Only the efforts made by researchers to address these issues will help us to determine whether or not the RFT approach to intellectual deficit will be sufficiently useful in making a real difference to the relational repertoires, educability and lives of those who most need our help. Armed with RFT as a conceptual framework and a touchstone for the development of practical interventions, behavior analysts are poised to make what might be our most impressive contribution yet to the world of psychology; the establishment of environmental control over "invariant traits ".

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