From the IRAP and REC Model to a Multi-Dimensional Multi-Level Framework for Analyzing the Dynamics of Arbitrarily Applicable Relational Responding

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Authors' Note This article was prepared with the support of an Odysseus Group 1 grant awarded to the first author by the Flanders Science Foundation (FWO) and partly funded by PS12014-59610P (Ministerio Economia y Competitividad, Spain) to the third author. Correspondence concerning this article should be sent to Dermot.Barnes-Holmes@ugent.be

Abstract

The article presents the beginnings of a conceptual framework for analyzing the dynamics of arbitrarily applicable relational responding (AARRing). The framework focuses on the dimensions and levels of AARRing that have been the focus of empirical and conceptual analyses in the literature on relational frame theory over the past 30 years. The name of the framework is abbreviated the MDML, and the conceptual and empirical context from which it emerged is presented. The framework currently consists of four dimensions, (i) coherence, (ii) complexity, (iii) derivation, and (iv) flexibility; and five levels of relational development, (i) mutual entailing, (ii) relational framing, (iii) relational networking, (iv) relating relations, and (v) relating relational networks. Within the MDML, each of the dimensions intersects with each of the levels, yielding 20 potential units of behavioral analysis, defined as functional-analytic abstractive relational quanta (abbreviated as FAARQs). Some of the conceptual and empirical implications of the MDML are considered, focusing in particular on how it highlights the dynamic properties of AARRing. Specific examples of how the MDML is (and may) impact upon research in relational frame theory are also presented.

Key words: Relational frame theory, multi-dimensional, multi-level, dynamics, arbitrarily applicable relational responding

From the IRAP and REC Model to a Multi-Dimensional Multi-Level Framework for Analyzing the Dynamics of Arbitrarily Applicable Relational Responding

A brief outline of the multi-dimensional multi-level framework for analyzing the dynamics of arbitrarily applicable relational responding (AARRing) was provided in a recent chapter, which functioned as an introduction to a section on relational frame theory (RFT) in the *Wiley Handbook of Contextual Behavioral Science* (Barnes-Holmes, Barnes-Holmes, Hussey, & Luciano, 2016). In that chapter, we argued that the proposed framework would provide a context for analyzing the dynamics of AARRing by conceptualizing such behavior in terms of multiple dimensions and multiple levels, and abbreviated the name of the framework, the MDML[1]. The key purpose of the current article is to present a more detailed or elaborate view of the MDML than was presented in the chapter of the recent handbook. In so doing, it should be clear that we are not seeking to replace RFT with something fundamentally new or different. Rather, we hope to focus on and extend those features of the original theory that appear to us to be the most important at the current time, but perhaps have remained somewhat understated in much of the early work on RFT. What we present here, therefore, is not an alternative to RFT as presented in the seminal volume (Hayes, Barnes-Holmes, & Roche, 2001), but an exercise in focusing on those features of the theory that seem to us to be most in need of emphasis as we move forward with the reticulating model of basic and applied science that serves to characterize contextual behavioral science itself (see Hayes, Barnes-Holmes, & Wilson, 2012).

What is the MDML and What Does it Offer?

At this point in an earlier version of the current paper we first presented the historical background to the MDML before describing the framework itself and explaining why we

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[1] As explained in greater detail later in the paper, the term “dynamics” refers to the ways in which the units of analysis, created by the intersections between the levels and dimensions specified within the MDML, interact with each other.

think it may be a useful tool within contextual behavioral science and perhaps beyond. During the review process, however, it became clear that it was important to begin with a basic outline of the MDML and to provide at least one or two examples of the motivation behind its development. Adopting this strategy requires that the reader who is unfamiliar with the MDML simply accepts the very brief description provided at this point, withholding final judgement of what we are proposing until later when we have put a great deal more flesh on the bones, so to speak. With that as a caveat, the reader is invited to examine Table 1, which shows that the MDML is composed of five levels of what we call relational development (mutual entailing, combinatorial entailing, relational networking, relating relations, and relating relational networks) and four dimensions of AARRing (coherence, complexity, derivation, and flexibility). As Table 1 illustrates, the five levels and the four dimensions intersect to create 20 units of behavioral analysis or what we call functional-analytic abstractive relational quanta. Although the MDML may appear quite daunting at first sight, it is important to appreciate from the outset that it is not a new model that makes specific predictions. Rather, the MDML is a framework that seeks to make explicit what basic researchers in RFT have been doing implicitly since the theory was first subjected to experimental analysis. In this sense, the MDML may be seen, in part, as a framework for orienting basic researchers in RFT to new possibilities for future research.

So, how does the MDML make the implicit, explicit? We would argue that whenever a basic RFT researcher conducts a study they typically combine at least one of the levels with one or more of the dimensions of the MDML. Even in a simple study on equivalence relations, the researcher selects a level (e.g., mutual entailment or symmetry) and then decides how many trials will be used to test for the entailed symmetry relations (e.g., 10), and how many trials the participants must get correct to define the performance as mutual entailment (e.g., 8/10). At this point, therefore, the number of opportunities to *derive* the entailed relations has been specified (i.e., 10) and the number of responses that must *cohere* with the relations is also determined (i.e., 8). In effect, the level and two of the dimensions of the MDML have been invoked. If relations other than symmetry are introduced to the study, or programmed forms of contextual control are involved, then complexity is also explicitly manipulated. And if the researcher attempts to change the test performances in some manner (e.g., by altering the baseline training) then flexibility enters the mix. As will become clear later in the article, RFT researchers, and to some extent stimulus equivalence researchers before them, have been doing this type of work for decades. All the MDML does is to make these scientific behaviors more explicit by placing them in a framework that specifies the 20 intersections between the well-established levels of relational development and the well-established dimensions along which the levels have been or could be studied.

According to the MDML, the 20 intersections specify the units of *experimental* analysis, not the levels or the dimensions *per se.* Although it is possible to state that mutual entailment, for example, is the bidirectional relation between two stimuli, mutual entailment can only be analyzed *experimentally* by specifying one or more of the dimensions (e.g., the tested relation must *cohere* in some pre-specified manner with the trained relation). As noted above, the MDML appears complex, with its 20 intersecting units of analysis. But as we have argued, it seems to capture what basic researchers in RFT have been doing for decades. It is also worth noting that science is littered with initially intimidating-looking taxonomies, including the now famous periodic table, which is introduced to children attending introductory science classes in school. Of course, one could still question the wisdom of making RFT even more complex or daunting than it already is by introducing the MDML. The short answer is that it brings a certain level of clarity to the field, where it was perhaps absent before, and clarity in science is often seen to be a valuable goal. Furthermore, the MDML appears to increase the emphasis on the potential dynamics involved in AARRing itself. In effect, the MDML highlights the myriad ways in which the units of analysis may interact with each other in both laboratory and “real-world” settings. Increasing the emphasis on the dynamics of AARRing seems important because it may help to build solid bridges between the basic laboratory science of RFT and the more applied and practice-based concerns found both inside and outside of contextual behavioral science.

We will argue below that RFT as a basic science, at least initially, focused almost exclusively on “demonstration-of-principle” research, where the focus was often on producing some sort of entailment effect that was either present or absent during a block of test trials. This type of research was of course necessary to test the core tenants of the theory, but as a result the behaviors typically targeted in basic RFT laboratories often appear “clunky” and not fluid enough to connect in any meaningful way with behaviors found in the “real-world” and certainly not those found in the clinic. Linking applied research and practice directly to basic research in RFT has thus presented an on-going challenge within contextual behavioral science (see Barnes-Holmes, Hussey, McEnteggart, Barnes-Holmes, & Foody, 2016; Hayes, Barnes-Holmes et al., 2012, for extended discussions).

One strategy to help develop the links between basic research and application/practice is to adopt middle-level terms that lack the precision of the analytic concepts in RFT, but aim to capture, in a broad sense, general clusters of the functional units of analysis found in the basic theory. The idea is that non-RFT researchers will find middle-level terms far easier to work with in dealing with the myriad challenges they face in clinical and other applied settings, while keeping them focused on broadly defined clusters of functional units of analysis. In addition, the use of middle-level terms may help basic RFT researchers to conduct studies that connect more directly with applied concerns. This is certainly one valuable strategy, but perhaps others should also be considered and adopted to avoid putting all our eggs in one basket, so to speak. In this context, we believe that the MDML may help to provide an additional “angle of attack” on building solid links or bridges between basic and applied researchers and practitioners in and outside of contextual behavioral science. The core idea is to take what basic RFT researchers have being doing all along and to place that scientific behavior into a framework (i.e., the MDML), which emphasizes the dynamic nature of AARRing so that it connects more directly with, for example, clinical phenomena. We will now provide a simple example of how we see this unfolding.

Imagine a client comes into therapy and during the first session says, “Deep down I am a bad person.” The therapist then asks, “How strongly do you believe this?” and the client replies “Without any doubt whatsoever – I really am bad to the bone.” The therapist then inquires, “How long have you believed that you’re so bad?” and the client replies, “Oh, for years and years – ever since I was in grade-school.” The therapist then asks, “And why do you think you are so bad?”, and the client replies, “I dunno really – I just am.” Finally, the therapist asks, “What would you say if I said that you don’t seem like such a bad person to me?”, and the client reacts slightly aggressively and retorts, “But you don’t know me – when you do, you’ll see how bad I really am.” At this point, the therapist writes down “Client is strongly *fused* with the thought that they are a bad person”.

The therapist has now used a middle-level term, “fusion” to describe the client’s behavior during their brief exchange. The use of the term in this context is entirely appropriate and will no doubt assist the therapist in moving forward with therapy and communicating with other therapists (e.g., during supervision sessions). But how might a basic RFT researcher approach this same exchange? The strategy we are suggesting here involves putting aside the concept of fusion, and middle-level terms generally, and focusing instead on the dynamics of AARRing, as specified within the MDML. Consider the following RFT “translation” of the previous client-therapist exchange.

When the client says “Deep down I am a bad person”, this is defined as mutually entailing the deictic-I (or verbal “self”) with “bad” (the first level of the MDML). When the client states that they have no doubt about their badness, the mutual entailing is defined as high in coherence (i.e., it is very true). When the client indicates that they have thought they are bad for many years, the mutually entailing is defined as low in derivation (i.e., the client has been thinking this almost habitually). When the client says “I just am” when asked why they think they are bad, the mutual entailing is defined as relatively simple at that point in the therapeutic exchange. Finally, when the client reacts negatively to the therapist suggesting that the client does not seem like a bad person, the mutually entailing may be defined as highly inflexible. In effect, rather than describing the client as fused with their thoughts, the MDML invites an analysis that focuses on the dynamics of AARRing.

Consider also, that slightly different responses from the client would require that different units within the MDML might be invoked. For example, if the client provided a long list of reasons why they are a bad person (rather than simply saying, “I just am”), the response might be better categorized as relational networking or even relating relational networks (e.g., if the client said, “I’m divorced, my kids don’t talk to me, I’m still drinking too much, I think I’m just about to get fired from work, and when my mom died last year I was too drunk to attend the funeral”). Also, if the client indicated that it had only recently dawned on them that they were a bad person (rather than thinking this for years), the network might be considered relatively high, rather than low, in derivation (i.e., as a verbal response that had only emerged recently in the client’s verbal repertoire). As we shall see later in the current article, all of foregoing types of analyses would, at least in principle, yield to basic RFT experimental analyses.

To be clear at this point, we are not suggesting that talking in this MDML-driven way is fundamentally better than simply using the term fusion – resolving that issue will remain an empirical matter. But what we are saying is that the MDML appears to provide a framework for developing an alternative strategy or approach (to a sole reliance on middle-level terms to bridge basic and applied concerns) in which the behavior of basic RFT researchers appears to connect more readily with the clinical domain. This seems like a potentially important move in the development of the reticulating model of science advocated within contextual behavioral science (see Hayes, Stanford, & Chin, 2016).

Having provided a brief outline of the MDML and our main motivation for developing it, we will now “back-up” a little and consider the conceptual and empirical contexts from which it emerged in our current thinking and research activity. Providing this background will help us to explain some of the finer details of the MDML itself.

The Dynamics of Relational Framing: The Need for New Procedures

As noted previously, much of the early research in RFT consisted of *demonstration-of-principle* studies that were designed to test the theory’s basic assumptions and core ideas. One of the defining features of this so-called demonstration research was a dichotomous approach to the experimental analysis of the generalized relational operant classes of AARRing. Thus, for example, participants were required to produce perhaps 18 out of 20 correct responses on a test for a frame of coordination to demonstrate that the relational frame had emerged. In this sense, the frame was either present or absent in the participant’s behavioral repertoire. A critical feature of the concept of operant behavior generally, however, is that it may vary in relative strength. The simple operant of lever pressing for food pellets in rats, for instance, may be relatively weak or strong. One way in which researchers have typically assessed such response strength is by measuring how long it takes for the operant to extinguish when the reinforcement contingency (between lever pressing and food pellets) is terminated. In effect, the longer the extinction process takes, the stronger the operant response class.

The important point to note here is that basic RFT research on AARRing did not appear to have an immediately obvious way to assess relative strength using extinction procedures. One key problem is that AARRing, by definition, involves behavior that emerges and may persist in the absence of direct reinforcement for particular response patterns because the contingencies are extremely molar. In other words, the generalized operants involved in many relational frames have very long reinforcement histories going back to early language learning. Using simple extinction procedures is unlikely to provide a realistic measure of the strength of such well-established operants. In addition, specific patterns of AARRing are often embedded functionally in larger relational networks, and thus attempting to extinguish such response patterns may be unsuccessful because they are maintained based on their coherence with the larger network (see Luciano et al., 2013, 2014). Imagine, for instance, that the Spanish word “perro” becomes coordinated with the English word “Dog” (when an English speaker is learning Spanish). Extinguishing this mutually entailed relation may be extremely difficult because “perro” will have become embedded in a large network of relations involving the many stimuli related to dogs, including non-coordinate relations (e.g., a perro is *not* a cat). Granted, some studies on AARRing examined the extent to which it was possible to change or reorganize patterns of relational responding that had been established within the laboratory (e.g., Healy, Barnes-Holmes, & Smeets, 2000; Pilgrim & Galizio, 1995), and thus could be seen as relevant to the question of relative strength of responding. However, this work also tended to focus on the dichotomous nature of relational frames in that it sought to establish new (re-organized) patterns that were either present or absent by the end of the experiment.

Within a few years of publication of the 2001 RFT book, therefore, the need to develop procedures that would provide a measure of relational framing that was non-dichotomous became increasingly apparent. As an example, research in the applied arena, particularly in acceptance and commitment therapy (ACT), began to rely more heavily on concepts such as psychological flexibility (Hayes, Stroshal, & Wilson, 2012; Törneke, Luciano, Barnes-Holmes, & Bond, 2016). Hence, questions around the flexibility of particular patterns of AARRing required a method for assessing relational frames in a non-dichotomous manner. The initial response to this need came in the form of the Implicit Relational Assessment Procedure (IRAP).

The IRAP as a Measure of Relational Responding "in Flight"

The initial inspiration for developing the IRAP came from the question, "How can we capture relational frames in flight?", essentially a question about the relative strength or probability of AARRing in the natural environment. In developing the IRAP, two separate methodologies were combined. The first was an RFT-based procedure called the Relational Evaluation Procedure (REP), which was used for training and testing multiple stimulus relations. The second was the Implicit Association Test (IAT), which had been developed by social-cognition researchers as a method for measuring what they conceptualize as associative strengths in memory (Greenwald, McGhee, & Schwartz, 1998). Combining the two procedures appeared to offer a measure of the strength of natural verbal relations, or AARRing (Barnes-Holmes, Hayden, Barnes-Holmes, & Stewart, 2008). Due to its close connection to the IAT, however, research with the IRAP quickly became dominated by studies focused on so-called implicit attitudes and implicit cognition more generally. Although this strategy provided a useful means of assessing the validity of the IRAP as a measure of natural verbal relations (Vahey, Nicholson, & Barnes-Holmes, 2015), it also detracted from a focus on RFT and AARRing *per se* (see Hussey, Barnes-Holmes, & Barnes-Holmes, 2015). We wish to emphasize, therefore, that the IRAP is also of interest to RFT researchers because it offers a method of assessing the relative strength of patterns of AARRing, which provide the functional-analytic units of human language and cognition.

The IRAP: A procedural and analytic overview. How does the IRAP measure the relative strength or probability of AARRing? The IRAP is a computer based task that requires an individual to respond to a series of screens that contain verbal stimuli (i.e., verbal as defined by RFT). Each trial presents a label at the top of the screen (e.g., the words “Flower” or “Insect”), and target stimuli in the middle of the screen (e.g., a positively or negatively valenced word, such as “Pleasant”, “Good”, “Unpleasant”, or “Bad”). Two response options are also presented on each trial that allow individuals to respond relationally to the label-target stimulus combination. For example, “Flower” and “Pleasant” might be presented with the response options “True” and “False”, and participants must confirm (pick “True”) or deny (pick “False”) that flowers are pleasant.

The IRAP essentially requires opposing patterns of responding across successive blocks. In a typical example, the combination of “Flower” and “Pleasant” on one trial requires the response “True” on one block and “False” on the next block. Of course, within the verbal community, certain relational responses are more likely to be reinforced than punished (e.g., affirming that flowers are pleasant), while others are more likely to be punished than reinforced (e.g., denying that flowers are pleasant). The IRAP is based on the assumption that, all things being equal, the more frequently reinforced response pattern, or one that is relationally coherent with it, will be emitted more rapidly (Barnes-Holmes, Barnes-Holmes, Stewart, & Boles, 2010). Note also, that the IRAP typically requires responses to be emitted under time pressure, thus revealing small or subtle differences in the relative speed with which participants can emit the two opposing patterns of responding. The IRAP is scored, therefore, by subtracting the mean response latency for one pattern from the mean for the opposite pattern. Differences in the mean latencies potentially reflect differences in the probabilities of the two patterns of responding, as established in the pre-experimental history of the individual. Thus, for example, responding ‘True” more rapidly than “False” would be expected for “Flower-Pleasant” for most individuals raised in an English-speaking verbal community.[2]

The relational elaboration and coherence model. In considering the types of effects observed on the IRAP, researchers have sometimes distinguished between brief and immediate relational responses (BIRRs) that are emitted quickly, and extended and elaborated relational responses (EERRs) that are emitted more slowly (Barnes-Holmes, Barnes-Holmes, et al., 2010; Hughes, Barnes-Holmes, & Vahey, 2012). The distinction was first formalized in the Relational Elaboration and Coherence (REC) model, offered as an RFT approach to implicit cognition (Barnes-Holmes, Barnes-Holmes et al., 2010; Barnes-Holmes, Murphy, Barnes-Holmes, & Stewart, 2010; Cullen, Barnes-Holmes, Barnes-Holmes, & Stewart, 2009). The basic idea behind the model is that the IRAP, and indeed other implicit measures, targets BIRRs rather than EERRs (Hughes et al., 2012). That is, the speed-criterion on each trial, almost by definition, forces the participant to emit a BIRR, the relative strength or probability of which is a function of the behavioral history of the participant with regard to functionally similar stimuli.

The REC model’s distinction between BIRRs and EERRs was largely *descriptive,* in that it did not indicate what variables might be involved in these two broadly defined patterns of behavior. A greater emphasis on *explanatory* concepts within the REC model was provided by focusing on levels of *derivation* and *relational complexity.*[3] The concept of

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[2] Generic predictions for IRAP effects are based on the assumption that “all things are equal”, but of course this is frequently not the case, especially in the context of natural verbal relations. For example, some of the earliest IRAP publications noted that response times on an IRAP may be influenced by *general* verbal biases typically found in natural languages, such as the tendency in English to respond “True” more quickly than “False” (Barnes-Holmes, Murphy et al., 2010, p. 62). Indeed, recent evidence indicates that IRAP effects may be influenced by these types of verbal biases and related variables (e.g., Finn et al., 2016; Maloney & Barnes-Holmes, 2016; O’Shea, Watson, & Brown, 2016). On balance, the impact of such variables on the predictive validity of the IRAP has yet to be determined, and it is indeed possible that the sensitivity of the IRAP to natural-language biases contributes towards its relatively strong predictive validity (see Vahey et al., 2015).

[3] The term “levels” is used simply to indicate that derivation and complexity may be conceptualized as dimensional, without pre-specifying a particular type or number of levels. Researchers may find it useful in certain contexts to specify discrete levels (e.g., low, medium, and high) in particular studies or in conducting

relational complexity recognizes that stimuli may be related in many ways, involving simple mutually entailed relations, combinatorially entailed relations (i.e., basic relational frames), and complex relational networks composed of multiple relational frames. According to the REC model, relational responding occurs along a continuum of “complexity” from low to high.[4] It is important to note the continuum-based nature of complexity in the REC model, and RFT generally, because boundaries that are often drawn between different conceptual categories are best treated as relatively “fuzzy.” For example, although a distinction is often made between the concept of a relational frame and a relational network, a frame may also be considered a simple network (of relations). The distinction is maintained between frames and networks, however, because it has proven extremely useful over the years to use the term frame, or framing, to refer to the relatively basic or simple relational networks that may be combined into increasingly complex networks involved in behaviors such as following detailed instructions and engaging in advanced problem solving (see Hughes & Barnes-Holmes, 2016b).

The concept of derivation recognizes that once a set of stimulus relations have been directly trained, such as A *same-as* B and B *same-as* C, a number of novel and untrained relations may be derived, such as C *same-as* A. According to the REC model, the first time a person derives the relation between C and A this response is highly derived because there is no direct history of reinforcement. However, as the C-A relational response is emitted subsequently, it becomes less and less derived from the originally trained A-B and B-C relations (i.e., because the C-A response pattern will gradually acquire its own direct history of reinforcement). For the REC model, relational responding occurs along a “derivation”

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specific types of data analyses, but specifying such units was not the purpose of the REC model and as will become clear it is also not the purpose of the MDML.

[4] Relational complexity is, of course, a multi-dimensional concept in that complexity itself may defined along more than one dimension, such as number of a relata, and/or frames, and/or contextual cues in a network. In some cases, therefore, identifying a single continuum of relational complexity may require appropriate multi-dimensional scaling (e.g., Borg & Groenen, 2005).

continuum from high to low. Critically, the typical IRAP and other measures of implicit cognition are most sensitive to relational responses that are low in derivation and complexity, a view that extends beyond the largely descriptive distinction between BIRRs and EERRs (see Hughes et al., 2012, for a detailed discussion; see also Barbero-Rubio, López-López, Luciano, & Eisenbeck, 2016).

The suggestion that levels of complexity and derivation are important properties of relational responding is broadly consistent with evidence, albeit limited, in the RFT literature. For example, a relational network containing two types of frames may produce higher response latencies, and different patterns of electroencephalogram (EEG) activity, than a network containing only one type (Barnes-Holmes, Regan et al., 2005). Furthermore, the extent to which a response has been derived in the past influences the probability of it being emitted quickly (Roche, Linehan, Ward, Dymond, & Rehfeldt, 2004) and accurately in the future (Healy et al., 2000). Hence, although RFT-based data that are consistent with the concepts of derivation and complexity pre-dated the IRAP and the REC model, the model provided the beginnings of a general framework for conceptualizing what appear to be important properties of AARRing. This in turn led to the MDML.

A Multi-Dimensional Multi-Level (MDML) Framework for Analyzing the Dynamics of AARRing.

As the name implies, the MDML aims to provide a framework composed of multiple dimensions and multiple levels. As will become clear, the various dimensions and levels may be seen as intersecting with each other. In presenting the MDML here, we will focus first on the dimensions, then on the levels, and finally on their intersections. Before continuing, however, it may be useful for the reader to examine Table 1 again in order to obtain a general overview of the MDML, which should help to support the detailed explication of the framework that follows.

Table 1

A Multi-Dimensional Multi-Level Framework Consisting of 20 Functional-Analytic Abstractive Relational Quanta or FAARQs; broken lines are used to separate the FAARQs to highlight that the boundaries between them may be considered relatively "fuzzy" (see text for details).

LEVELS	**DIMENSIONS**			
	Coherence	**Complexity**	**Derivation**	**Flexibility**
Mutually Entailing	**Coh/Mut-Ent**	**Cpx/Mut-Ent**	**Dev/Mut-Ent**	**Flx/Mut-Ent**
Relational Framing	**Coh/Frame**	**Cpx/Frame**	**Dev/Frame**	**Flx/Frame**
Relational Networking	**Coh/Net**	**Cpx/Net**	**Dev/Net**	**Flx/Net**
Relating Relations	**Coh/Rel-Rel**	**Cpx/Rel-Rel**	**Dev/Rel-Rel**	**Flx/Rel-Rel**
Relating Relational Networks	**Coh/Rel-Net**	**Cpx/Rel-Net**	**Dev/Rel-Net**	**Flx/Rel-Net**

Dimensions of AARRing. The primary purpose of the MDML is to focus on the dynamic properties of AARRing. The first step in refocusing RFT in this regard is to identify the various dimensions of AARRing that may be impacted upon by various contextual variables. At the time of writing, four such dimensions appear to be critically important (others may emerge through further conceptual and empirical analyses) and are labelled within the MDML as; (i) relational coherence, (ii) relational complexity, (iii) derivation, and (iv) relational flexibility.

As explained earlier, the four dimensions have been invoked (if only implicitly) for decades by both RFT and stimulus equivalence researchers. For example, an experimental analysis of symmetry (a mutually entailed relation of coordination) requires that the trained and tested relations are only considered *coherent* when they are the same (i.e., A *same-as* B entails B *same-as* A), and the concept of *flexibility* may be invoked when a tested relation is easily modified by competing contingencies (see Pilgrim & Galizio, 1995). Nevertheless, brief and relatively informal definitions of each of these dimensions are provided here; more detailed treatments appear in recently published sources, which are cited below. *Relational coherence* refers to the extent to which a given pattern of AARRing overlaps functionally with previous patterns of AARRing that were reinforced (or at least not punished) by the verbal community (see Hughes & Barnes-Holmes, 2016a). For example, if you are told that A is taller than B, stating thereafter that B is shorter than A would not typically be punished. *Relational complexity* refers to the intricacy or density of a pattern of relational responding (see Hughes & Barnes-Holmes, 2016a). For example, a combinatorially entailed relational response involving three relata (e.g., A *same-as* B and B *same-as* C entails C *same-as* A) is less complex than one involving four (e.g., A *same-as* B and B *same-as* C and C *same-as* D entails D *same-as* A). *Derivation* refers to how “well practiced” an AARR has become (see Barnes-Holmes, Barnes-Holmes et al., 2016). Given that a response pattern derived for the first time is highly derived (i.e., novel or emergent), derivation reduces as that pattern becomes more practiced. *Relational flexibility* refers to the extent to which a particular pattern of AARRing may be modified by a contextual variable (see Barbero-Rubio et al., 2016; O’Toole & Barnes-Holmes, 2009). For example, relational flexibility may be shown when an individual switches back and forth with ease between two opposing patterns of AARRing in an IRAP.

In targeting these four dimensions of AARRing within the MDML framework it is important to emphasize their potential for highlighting the interactive or dynamic properties of AARRing itself. For instance, the highly complex patterns of AARRing involved in reading and understanding a novel may produce changes in one or more properties of AARRing when the novel is read for a second time. Across readings, levels of derivation may reduce because the tendency to infer certain conclusions before reaching the end of the novel on its first reading are not required when it is read again. As a corollary, relational complexity may also reduce because fewer derivations or inferences are actually produced during the second reading.[5] On balance, it is possible that new derivations or inferences emerge, as the reader "sees or appreciates links and connections" within the novel that were missed the first time it was read. In this case, levels of derivation and complexity may remain relatively stable across the readings, but levels of relational coherence may increase, as the story "makes more sense" on its second reading. Although this example highlights the dynamic nature of the dimensions of AARRing within the MDML, the intersection of the four dimensions with multiple levels of relational development create additional dynamics (see below).

Levels of relational development. In addition to the four dimensions of AARRing, the MDML identifies five levels of relational development that intersect with each dimension. These are labelled as; (i) mutual entailing, (ii) relational framing, (iii) relational networking, (iv) relating relations, and (v) relating relational networks. In describing these as levels of relational development, we are not suggesting that they are rigid or invariant "stages". Rather, lower levels contain patterns of AARRing that provide an important historical context for the patterns of AARRing that occur in the levels above. In general, the different levels are based on a combination of well-established assumptions within RFT and, where possible, empirical evidence. It is also important to emphasize that because the five levels of relational development intersect with the four dimensions, AARRing may shift across levels in a dynamic manner contingent on changes along one or more of the dimensions. For example, a reduction in derivation may involve a corresponding reduction in relational complexity, and thus AARRing that was categorized initially at one level in the

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[5] Although the dimensions of relational complexity and derivation may frequently co-vary, they are best conceptualized as independent properties of AARRing. To understand why, imagine a young child who learns two relations; *A same-as B, B same-as C*. When the child is then asked what is the relation between C and A, she may reply "if A is the same as B and B is the same as C, then C is the same as A". If the child continues to answer the question in this way each time she is asked (i.e., always deriving the C-A relation through B), derivation may be conceptualized as reducing (as the relational response acquires its own behavioral history), while relational complexity remains constant. If, however, the child eventually begins to answer the question simply by replying, "C is the same as A," both derivation and complexity may be conceptualized as reducing (note, we are assuming here that the child is not continuing to derive the C-A relation *privately* through B).

framework may be categorized subsequently at a lower level (we shall return to this issue later). In identifying the five levels, it seemed important to have, or be readily able to generate, relevant basic laboratory examples of AARRing at each level. Maintaining a close connection between the MDML and basic research in this way will ensure that the conceptual framework continues to be explored, developed, and/or refined through on-going experimental analyses.

Mutual entailing. Young children in the early stages of language development may demonstrate mutual entailing without combinatorial entailing (Lipkens, Hayes, & Hayes, 1993). Such patterns of AARRing do not, therefore, meet the definitional criteria for relational framing (i.e., mutual *and* combinatorial entailing). Nevertheless, mutual entailing is almost certainly a critical, albeit limited, relational “precursor” for combinatorial entailing (see Luciano, Gómez-Becerra, & Rodríguez-Valverde, 2007). Mutual entailing is thus conceptualized as the first, and a separate, level in the MDML. As an aside, recent conceptual analyses of the evolutionary origins of AARRing (Hayes & Sanford, 2014) have suggested that mutual entailing likely emerged first as an instance of a social act within a highly cooperative species (i.e., humans). Although plausible, the MDML was not designed to comport with any particular hypothesis of how AARRing evolved; mutual entailing is identified as a separate level of relational development within the MDML based simply on available data (albeit limited) within the existing RFT literature. As we shall see later, however, the framework does suggest connections between RFT and evolution science that could be tested empirically.

Relational framing. The concept of relational framing is well established in the RFT literature, and it provides the minimal unit of analysis that is required to demonstrate three core properties of AARRing; mutual entailing, combinatorial entailing, and the transformation of functions.[6] As such, relational frames are the simplest relational networks that allow us to identify a wide range of distinct patterns of AARRing. Relational framing is thus conceptualized as a separate level in the MDML.

Relational networking. The concept of the relational network is also well-established in the RFT literature, and as noted above relational frames are considered to be examples of basic or simple relational networks. Within the MDML, and RFT generally, a distinction is made between relational framing and networking because the latter likely develops only after some basic examples of the former have been established in an individual's behavioral repertoire. For example, relational networking including four or more relata and/or combinations of different relational frames would likely develop only after AARRing with the relevant three-element frames had been learned. At the most basic or trivial level, therefore, the distinction between a frame and a network could be made between a network that contained the minimum number of relata necessary to demonstrate mutual and combinatorial entailment (e.g., A *same-as* B and B *same-as* C, yielding C *same-as* A) and a network that extended beyond this by one relata (i.e., A *same-as* B, B *same-as* C, and C *same-as* D, yielding, for example, D *same-as* A). At a less trivial level, however, the distinction could involve networks in which different patterns of relational framing combine (e.g., A *same-as* B, B *same-as* C, C *larger-than* D, and D *larger-than* E, yielding, for

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[6] In RFT, any test for mutual and/or combinatorial entailing will involve a transformation of functions, if only in a relatively limited manner. Even in a basic test for symmetry in a stimulus equivalence experiment (e.g., train A-B and test for B-A), the function of a reinforced sample stimulus (A) transforms into the function of a comparison stimulus, and the function of the reinforced comparison stimulus (B) transforms into the function of a sample stimulus (i.e., B becomes the sample and A becomes the comparison). In such basic studies, various properties of the experimental context are assumed to function as Crels and Cfuncs, which control the observed transformation of matching-to-sample functions during the critical test phases. In more elaborate studies, however, specific contextual cues may be pre-trained (e.g., Steele & Hayes, 1991) and additional transformations of functions beyond those involved in matching-to-sample may be explored (e.g., Dymond & Barnes, 1995). From the perspective of the MDML framework, these more elaborate studies provided critical empirical evidence to support the basic concepts and assumptions of RFT. It would be a mistake, however, to conclude that Crel and Cfunc control, and transformation of functions, are absent in the more basic stimulus equivalence research. In the current article, therefore, examples of mutual and/or combinatorial entailing will be provided in which specific Crels, Cfuncs, and transformations of function are not specified, but are nonetheless assumed to be operating.

example, E *smaller than* A). Learning to respond in accordance with combinations of interrelated relational frames, has always been seen as central to the RFT account of advanced human verbal or cognitive abilities, such as rule-following (Barnes-Holmes, O'Hora et al., 2001), rule-generation (Barnes-Holmes, Hayes, & Dymond, 2001), and abstract problem-solving (Hayes, Gifford, Townsend, & Barnes-Holmes, 2001). Although relatively limited, relational-network models of rule-governed behavior, based on RFT, have been reported in the literature (e.g., O’Hora, Barnes-Holmes, Roche, & Smeets, 2004; O’Hora, Barnes-Holmes, & Stewart, 2014). Within the MDML, the distinction between relational framing and relational networking is seen as critical, because learning to respond in accordance with basic relational frames provides an important historical context for learning to respond in accordance with more complex relational networks, particularly those that involve interrelated frames.

Relating relations. The concept of relating relations has been central to the RFT account of analogical and metaphorical reasoning (e.g., Stewart, Barnes-Holmes, Hayes, & Lipkens, 2001; Stewart & Barnes-Holmes, 2004). The basic phenomenon involves training and testing for at least two sets of separate combinatorially entailed relations. For example, two frames of coordination may be established (e.g., A1 *same-as* B1, B1 *same-as* C1, yields C1 *same-as* A1; and A2 *same-as* B2, B2 *same-as* C2, yields C2 *same-as* A2). Subsequently, tests are used to determine if participants will relate one derived relation to the other derived relation, such that C1 *same-as* A1 is coordinated with C2 *same-as* A2. More informally, participants appear to be reasoning analogically that C1 is to A1 as C2 is to A2. Note that the predicted pattern of AARRing does not result in a single frame of coordination containing four stimuli, but requires relating a derived relation between two stimuli to a second derived relation between two stimuli. As such, the observed pattern of responding extends beyond the concept of a basic relational network containing four or more stimuli, thus suggesting a more advanced level of relational development than that involved in relatively simple networks. Indeed, empirical research indicates that young children (aged 4-5) demonstrate considerable difficulty relating derived relations (see Stewart & Barnes-Holmes, 2004) and yet are capable of following rules and instructions (i.e., responding in accordance with relational networks; see Tarbox, Zuckerman, Bishop, Olive, & O'Hora, 2011). Furthermore, it seems likely that learning, at least initially, to respond in accordance with relational networks that extend beyond basic relational frames may facilitate learning to relate derived relations to derived relations. It thus seems useful, at least at this point, to distinguish within the MDML between relational networking and relating relations.

Before continuing, it seems important to note that although relating relations has been used as a possible model of analogical and metaphorical reasoning, the basic phenomenon may extend beyond this domain. For example, analogical reasoning typically involves coordinating two separate relations based on the fact that they are similar along one or more dimensions. However, given appropriate contextual cues, relating relations that are opposite to each other or differ in some way may be observed. For example, given a Crel for *opposite* and a Cfunc for *relative size*, "car is to truck" may be related (as opposite) to "elephant is to dog" because *smaller-than* is opposite to *bigger-than.* Such examples of "analogical reasoning" in natural language may be quite rare due to their apparent lack of utility, but unusual ways of relating relations are entirely predictable inside the MDML and RFT more generally.

Relating relational networks. The concept of relating relational networks within the MDML is extremely broad in scope in that it contains all classes of AARRing above and beyond those captured by the previously described levels. In time, it seems likely that it will be useful to divide this level into finer sub-levels of relational development, but given the paucity of basic RFT research at this level it seems wise, at this point, simply to identify one final broad level. A very basic example of relating relational networks could involve first training two separate networks (e.g., Network 1, A1 *same-as* B1, B1 *same-as* C1, C1 *same-as* D1; Network 2, A2 *same-as* B2, B2 *same-as* C2, C2 *same-as* D2). Subsequently, the test for relating networks could determine if some derived version of Network 1 (e.g., D1 *same-as* B1 *same-as* A1) is coordinated with a derived version of Network 2 (e.g., D2 *same-as* B2 *same-as* A2). In one sense, the distinction between relating relations and relating relational networks may seem trivial because the key difference rests simply on the number of relata involved (i.e., two in each derived *relation* in the case of relating relations versus three in each derived *network* in the case of relating networks). The distinction becomes clearer and perhaps more important, however, as the number of relata and relational frames involved in the networks increase (see Ruiz & Luciano, 2011, 2015). Imagine, for example, training two five-element networks each involving two relational frames (e.g., Network 1, A1 *same-as* B1, B1 *same-as* C1, C1 *larger-than* D1, D1 *larger-than* E1; Network 2, A2 *same-as* B2, B2 *same-as* C2, C2 *larger-than* D2, D2 *larger-than* E2). The test for relating networks could thus involve determining if a derived version of Network 1 (i.e., E1 *smaller-than* D1 *smaller-than* C1 *same-as* A1) is coordinated with a derived version of Network 2 (i.e., E2 *smaller-than* D2 *smaller-than* C2 *same-as* A2).

We should point out at this stage, that the foregoing examples of relating relational networks fails to emphasize the critical role played by subtle or highly refined forms of contextual control in determining how networks may be related. For example, two relational networks could be related to each other based on variables such as the number of relata in each network, or the number of different types of relations (i.e., Crels) in the networks, or some combination of both variables. Derived Networks 1 and 2, as described above, could thus be coordinated with each other because they both contain four relata (i.e., E, D, C, & A) *and* two Crels (*same-as* and *smaller-than*). Alternatively, the networks could be related as *distinct* from each other if, for example, the derived version of Network 2 contained only three relata and two Crels (e.g., "E2 *smaller-than* C2 *same-as* A2"). Consider also that the two networks that were originally *trained* may be seen as relationally coherent with each other in that they both possess the same "relational structure" (i.e., "A *same-as* B *same-as* C *more-than* D *more-than* E). Thus any *derived* version of Network 1 may be coordinated with any other derived version of Network 2 if "relational coherence in the *trained* networks" provides the contextual basis for coordination. For example, derived Network 1 (i.e., E1 *smaller-than* D1 *smaller-than* C1 *same-as* A1) would be coordinate with "A2 *same-as* C2 *more-than* E2", even though they differ in terms of number of relata and Crels (because both networks are derived from trained networks that cohere with each other). In any case, these relatively simple examples of contextual control over the relating of relational networks serve to highlight that this final level of relational development provides an extremely broad category of AARRing, which will require extensive conceptual and empirical analyses over the coming years.[7]

At the time of writing, the current authors were not aware of any published basic research studies in RFT that had demonstrated the relating of complex relational networks in laboratory settings (cf. Ruiz & Luciano, 2011, 2015). We anticipate that conducting research

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[7] The foregoing examples of contextual control over relating networks are quite abstract in the sense that the networks do not form parts of much larger or extensive networks involving stimuli or events in the natural environment. Critically, more naturalistic networks often provide the basis for other networks that may serve as relevant contextual cues for relating the relational networks. There is an almost infinite number of possible examples, but for illustrative purposes we will consider a hierarchical network containing four relational networks with contextual cues controlling the relating of the three "lower-level" networks to each other. First, the "stories" or networks of Martin Luther King Jr., Malcom X, and Mahatma Ghandi may be hierarchically related to the superordinate network, "Famous Civil Rights Campaigners". Second, the relations among the three subordinate networks may differ depending upon contextual cues provided by specific parts of those three networks. For instance, Martin Luther King and Malcolm X may be coordinate with each other, and distinct from Ghandi, in the context of "African-American civil rights campaigners", but King and Ghandi may be coordinate with each other, and distinct from Malcolm X, in the context of "advocates of nonviolent resistance." Although this example may appear relatively simple to a verbally sophisticated and reasonably well-educated adult, the required level of relational complexity combined with the subtleties in contextual control, as seen through the lens of RFT, highlights why relating relational networks is currently placed at the final level of the MDML.

in this area will be particularly challenging but at least some basic models could be produced based on existing studies. For example, the models of rule-governed behavior reported by O’Hora et al. (2004, 2014) could be adapted or extended for this purpose. In these studies, a number of Crels were pre-trained (“Same,” “Different” “Before,” and “After”), and then these cues were used to establish a range of two-element stimulus relations. These relations included different colored keys (e.g., Green-key *same-as* B1, B1 *same-as* C1; Red-key *same-as* B2, B2 *same-as* C2, Yellow-key *same-as* B3, B3 *same-as* C3; Blue-key *same-as* B4, B4 *same-as* C4). Four separate relational frames, with each one containing a different colored key, could thus be derived. Individual stimuli from the four frames were then presented with the “Before” and “After” cues in a manner that allowed for the derivation of relational networks or rules for pressing the four colored keys in specific sequences. For example, the relational network “C1 before C2 before C3 before C4” frequently controlled the response sequence: press Green-key then Red-key then Yellow-key then Blue-key. The important point here is that this type of procedure could be adapted to present not just a single network on each trial (as a type of rule or instruction) but two or more networks, which could then be related to each other.

As noted previously, relational networks may be related to each other in many different ways, depending on appropriate contextual cues, and we have only presented relatively simple examples here. We do recognize, however, that exploring the complex nature of relating relational networks, particularly as the relating comes under increasingly subtle and refined forms of contextual control, will require considerable ingenuity and innovation by RFT researchers. Nevertheless, adapting procedures that have been used successfully in previous studies, in areas such as modelling rule-governed behavior, would seem like a potentially useful place to start. Indeed, such work will be important if the four dimensions of the MDML (coherence, complexity, derivation, and flexibility) are to be explored at the level of relating relational networks in the basic RFT research laboratory.

As an aside, one of the reviewers of an earlier version of the current paper suggested that translational research may be of greatest value when analyzing the enormous degrees of complexity involved in relating relational networks. As the reviewer pointed out, “even though relating relational networks would be enormously difficult to model in the laboratory, it is presumably a set of functional relations that occur on a relatively regular basis in real life. . . there might be a way to design research that taps into those complex repertoires, perhaps depending on some or many previously established functions. This type of research would not have anywhere near the same control as all-arbitrary lab research but it might serve as a bridge between RFT and what most of the rest of the world recognizes as something tangible and important.” We could not agree more with the reviewer on this point, and indeed it is our hope that the MDML will have a useful impact in designing and conducting such translational research (see, for example, Persicke, Tarbox, Ranick, & St. Clair, 2012).

The MDML framework. We will now present an overview of the MDML itself (see Table 1). Each of the four dimensions intersect with the five levels of relational development, thus yielding 20 individual units of behavioral analysis, which we define as functional-analytic abstractive relational quanta or FAARQs (pronounced “farks”). As such, a FAARQ is conceptualized as a unit of analysis (or package) of organism-environment functional relations involved in specific patterns of the abstracted functional-analytic concept of arbitrarily applicable relational responding (or AARRing). The primary purpose of the MDML, and FAARQs in particular, is to provide a framework for basic and applied researchers, and practitioners, to conceptualize, discuss, and analyze what appear to be important properties of AARRing. To help support this purpose, and to assist in maintaining brevity in communicating about the MDML, abbreviations for each of the 20 FAARQs are presented in Table 1.

In suggesting a framework of 20 FAARQs, it is important to see them as fuzzy categories, thus they are separated in Table 1 by dashed rather than solid lines. There are three main reasons for treating the boundaries between FAARQs in this manner. First, as noted previously, the relationships among the four dimensions should be seen as dynamic in that changes in one may involve changes in another (e.g., decreases in derivation may co-occur with decreases in complexity).

Second, changes in the various dimensions of AARRing may be seen as involving changes in the level at which that AARRing is located within the MDML. Imagine a study, for example, in which a participant is trained to form two relatively complex relational networks: Network 1, A1 *same-as* B1, B1 *same-as* C1, C1 *same-as* D1, and D1 *different-to* E1; and Network 2, A2 *same-as* B2, B2 *same-as* C2, C2 *same-as* D2, and D2 *different-to* E2. Now imagine that the two most distantly related stimuli from each of the two relational networks (A1 *different-to* E1 and A2 *different-to* E2) are presented to the participant who is required to derive a relation of coordination between these two pairs of stimuli. Initially, this pattern of AARRing would likely be categorized as relating relational networks because relating A to E in each case involves a multi-frame relational network. However, across many derivations (i.e., relating A1 to E1 and A2 to E2), the AARRing might be better conceptualized as shifting to the lower level of relating-relations because deriving the two full networks on each test trial is no longer required. Or more informally, the participant stops “working through” each of the networks privately before coordinating them and simply emits the same response that was emitted many times previously. Indeed, it is possible that eventually our hypothetical participant would be unable to derive (or, more informally, recall) all of the possible relations from the two initially trained networks while still correctly coordinating the two A *different-to* E relations. At this point, it would certainly seem appropriate to consider the AARRing involved as having dropped a level within the MDML framework.

The third reason to treat FAARQs as fuzzy categories is because there are many examples of AARRing that do not fit neatly into a specific level of relational development. Consider, for instance, a simple extension of relating-relations in which three, rather than two, relations are related (e.g., C1-A1 *same-as* C2-A2 *same-as* C3-A3). Should this pattern of AARRing be categorized as relating-relations or relating relational networks? If one thinks of the MDML as consisting of fuzzy categories, a reasonable answer is that such patterns of AARRing may be considered as lying at the boundary between the two levels. Indeed, the question could be rendered, at least in part, an empirical issue by determining if learning to relate increasing numbers of relations to each other in young children facilitates learning to relate relational networks. Or to put it another way, perhaps as a child learns to relate increasing numbers of relations to each other, the AARRing involved becomes functionally equivalent to relating networks. In this sense, the fuzzy boundaries of the MDML may be seen as generating potentially useful empirical questions concerning the learning or development of increasingly advanced levels of AARRing. Insofar as this is the case, the production of relevant empirical evidence will enable us to determine the pragmatic utility of the concept of the FAARQ as a fuzzy category, and the MDML in general. Indeed, such work could feed back into the future development and refinement of the MDML itself.

The general strategy we are offering here deserves to be emphasized lest we be misunderstood. We are not making ontological claims for the MDML. As with any contextual behavioral science concept, framework, or theory, it should be seen as a verbal stimulus that influences scientific behavior within a relevant domain (in this case, human language and cognition) in a manner that is designed to increase behavioral prediction-andinfluence with precision, scope, and depth. We therefore see the MDML as a work in progress and certainly not the final word on the matter. Additional dimensions may be added and levels (or sub-levels) of relational development inserted (or perhaps separate levels collapsed) in subsequent iterations of the framework, based on conceptual and/or empirical progress over the coming years. What we offer here, therefore, should be seen as a beginning, not the end of an intellectual or scientific (inductive) journey.

The 20 FAARQs: A brief review. In reflecting upon the MDML as presented in Table 1, it should be relatively clear that each of the four dimensions of AARRing could be subjected to experimental analyses at each of the five levels of relational development. Working through possible examples of such analyses for each of the 20 FAARQs is beyond the scope of any single article, but a brief review of some of the analytic units seems warranted.

In starting with the dimension of relational coherence, the MDML indicates it may be applied at each of the five levels of relational development. For example, mutually entailed relations may be deemed coherent (e.g., A *same-as* B entails B *same-as* A) or incoherent (e.g., A *same-as* B entails B *different-to* A). Indeed, it is possible to think of examples of coherence, even at the level of mutual entailment, as existing along a dimension. For example, “A *same-as* B entails B *similar-to* A” could be seen as less coherent than the former example but more coherent than the latter, because “same” and “similar”, although not synonymous, are closer in meaning than “same” and “different.” This example, as with all of the others that follow, should not be treated as some sort of taxonomy of logical reasoning or ontological categories of thought, but rather as potential sources of inspiration for experimental and applied analyses. Examples of relatively coherent versus incoherent FAARQs across the remaining four levels of relational development may be imagined and thus could also yield to experimental analyses in both basic and applied research contexts.

For example, relating the relations, A *same-as* B and X *same-as* Y, as coordinate may be defined as more relationally coherent than coordinating the relations A *same-as* B and X *similar-to* Y (again, because *same* and *similar* are not exactly synonymous).

As noted previously, in Footnote 3, the dimension of relational complexity *per se* may be seen as multi-dimensional, but again relevant examples, that may be subjected to experimental analysis, may be imagined for each of the five levels. At the level of mutual entailment, for example, “A *same-as* B entails B *same-as* A” may be seen as less complex than “A *more-than* B entails B *less-than* A” because one versus two types of Crels is involved across the two examples, respectively. The MDML is not designed to specify exactly which instances of AARRing may be more or less complex than other instances. For example, is a six-element relational network involving only one relation (i.e., coordination) more or less complex than a four-element network involving two relations (e.g., coordination and opposite)? One of the functions of the MDML is to highlight these types of variables and to indicate that they may be important to address in basic, applied, and conceptual analyses.

With respect to the dimension of derivation, the MDML indicates that it could yield to experimental analyses at each of the five levels. Insofar as any pattern of AARRing at any of the five levels of relational development may generate a derived relational response, then derivation may be seen as reducing each time an instance of such a response is emitted (i.e., as the pattern becomes less and less derived from the original source of the derivation). At the level of mutual entailment, for example, learning “A *same-as* B” may produce the derived response “B *same-as* A”, which may be explicitly reinforced, or at least not punished, by the verbal community. As the “B *same-as* A” response is emitted repeatedly thereafter, the extent to which it may be seen as derived from the original “A *same-as* B” learning declines. The same general view may be applied at the level of relational framing or networking, and so on.

We should also note that the first time that a young child responds in accordance with a particular relational frame, that frame itself may be seen as derived entirely from a history of reinforced multiple-exemplars. Once the frame itself is derived, however, it may be seen as less and less derived from the *initial* source of exemplar training each time the child responds in accordance with that frame. As noted by Barnes-Holmes, Barnes-Holmes et al. (2016), this reduction in derivation seems important because it may facilitate novel forms of derivation at higher levels of relational development. We shall return to this issue subsequently because it serves to highlight the interactive and dynamic nature of the MDML.

Finally, with respect to the dimension of relational flexibility, the MDML indicates that it could yield to experimental analyses at each of the five levels. Specifically, given that any of the five levels of AARRing may be subject to the impact of some form of moderating contextual variable or variables, it should be possible to determine the relative flexibility of that AARRing by examining how readily it is altered by the introduction of the relevant variable(s). As noted earlier, switching back and forth between two opposing patterns of AARRing with relative ease, as is required when completing an IRAP, provides a ready example of relational flexibility (see O'Toole & Barnes-Holmes, 2009). A basic experimental analysis of such flexibility could thus involve training and testing a particular instance of AARRing and then inserting the derived mutually entailed relation, or frame, or network, etc. into an IRAP. The relative size of the difference score between blocks of trials that required AARRing that was consistent versus inconsistent with the originally derived patterns could thus provide at least one measure of relational flexibility (see Bortoloti & de Rose, 2012, for an example of this general research strategy).

The MDML: What does it add? Having described the MDML framework and how it may be used to generate basic experimental analyses of AARRing, it seems wise to consider if it brings something new to the table. In one sense, the answer to this question must be negative because the MDML is not an alternative theory to RFT. Rather, it should be seen as an extension or elaboration of the account as laid out in the original Hayes, Barnes-Holmes et al. (2001) volume. On balance, the MDML does provide a context for focusing on the *dynamics* of AARRing in a manner that was at least understated in the original treatise. In this penultimate section, therefore, we will provide some recent examples of how the MDML is helping us to conceptualize and analyze these dynamics. The material will be relatively brief because the relevant work, both conceptual and empirical, is very much in play and under-developed in some cases.

Moving from BIRRs and EERRs, to the REC model, and to the MDML and the dynamics of AARRing. First and foremost, it is worth emphasizing that the MDML is in one sense at the cutting edge of a program of research that was initiated approximately 12 years ago and has moved from a focus on the relatively narrow domain of implicit attitude research to the far broader domain of the dynamics of AARRing. At the very least, therefore, the MDML constitutes a step beyond the REC model, and in this sense is novel or new. For example, the MDML readily accommodates dynamic interactions in AARRing across levels of relational development. Consider, for example, the findings reported by Carpentier, Smeets, and Barnes-Holmes (2002, 2003; see Stewart & Barnes-Holmes, 2004, for a review), which showed that young children (aged 5 years) tend to fail tests for relating derived relations to derived relations, unless they are first exposed to tests that allow them to derive the individual relations (adults do not require this pre-exposure). In other words, it appears that AARRing at the level of relational framing itself is not sufficiently well established in the behavioral repertoires of most 5-year old children to support the relating of frames to frames without providing the opportunity to derive the individual frames beforehand. Such a finding is readily accommodated within the MDML. As suggested previously, the first time that a young child responds in accordance with a specific relational frame, the framing may be seen as derived entirely from the previously reinforced multiple exemplars. Once the framing is derived, however, it may continue to be reinforced across subsequent exemplars, and according to the MDML becomes less and less derived from the initial source of exemplar training. This reduction in derivation at one level of the MDML, however, appears to facilitate derivation at higher levels of relational responding, such as that observed for the relating of derived relations to derived relations. In other words, reductions in derivation at one level of the MDML may lead to increases in derivation at other levels, thus highlighting the dynamic nature of AARRing that the MMDL framework seeks to capture and emphasize.

Exploring the behavioral dynamics of the IRAP. The MDML also encourages a thorough and systematic analysis of the behavioral dynamics involved in the IRAP, but not as a measure of implicit cognition *per se* (see Barnes-Holmes, Barnes-Holmes et al., 2016). Although we are only beginning to mine this particular vein of research, it is here that the MDML is proving to be particularly useful. In other words, questions about the various patterns of behavior that we observe on the IRAP, and the variables that seem to be important in producing those patterns, are now being caste in terms of the MDML. Consider, for example, the two patterns of AARRing that are required on a *Flowers-Pleasant* trial-type. All things being equal, a relatively large IRAP effect would be expected in a history-consistent direction (i.e., responding “True” more quickly than “False”). Such an IRAP effect may be conceptualized within the MDML as AARRing for which the FAARQs are high in coherence, low in complexity, low in derivation, and low in flexibility during history-consistent trials, but during history-inconsistent trials coherence reduces, and complexity, derivation, and flexibility increase. In other words, confirming that flowers are pleasant is likely to cohere with the reinforcement contingencies operating in the wider verbal community; the required relational response is not particularly complex (i.e., confirming a mutually entailed relation); will have been derived numerous times in many contexts (e.g., when buying or receiving flowers as a gift); and may be relatively inflexible (assuming that there are very few, if any instances, in which flowers have acquired aversive functions in the natural environment).

It is also worth noting that in suggesting that the AARRing increases in complexity during history-inconsistent trials, the FAARQs involved could be seen as occurring at a higher level within the MDML framework. Specifically, the FAARQs during history-consistent trials simply involve confirming a mutually entailed relation, but AARRing during history-inconsistent trials may involve an additional relational response. In effect, participants may initially confirm the “flowers-pleasant” mutually entailed relation *privately* (i.e., “that’s true”), and then respond to that private response itself with “but not now” and thus emit the correct response for that block of trials on the IRAP. In summary, participants mutually entail the established relation between flower and pleasant during history-consistent trials, but during history-inconsistent trials the mutually entailed response is extended with an additional response involving the relational frame of distinction. The latter pattern of AARRing, therefore, may be more appropriately categorized within the MDML as involving relational networking, rather than mutually entailing.

We should emphasize that the foregoing provides a relatively simplistic analysis of the IRAP effect and we recognize that it is moderated by numerous variables (see Finn, Barnes-Holmes, Hussey, & Graddy, 2016; Maloney & Barnes-Holmes, 2016). The point, however, is that we are currently using the MDML to help us unpack this very complexity, thus generating new types of research questions that appear to have a direct bearing on clinically relevant issues. Is it possible, for instance, to establish AARRing in the laboratory involving FAARQs with low levels of derivation but high levels of flexibility, and if so how is this achieved? Imagine that a complex relational network is trained and tested in such a manner that all of the coherent parts of the network are derived many times, and thus it produces relatively strong and persistent IRAP effects. However, one small part of the network contains an incoherent element but remains untested, until a "therapeutic intervention" reveals the incoherence. Does targeting and revealing relational incoherence in a network help to undermine relational inflexibility (i.e., reduce the size of an IRAP effect) in the laboratory environment? Analyzing the dynamics of AARRing in this way could be important clinically, because there are relevant examples where some patterns of AARRing have been derived almost countless times in the history of a client, and will likely remain so in the natural environment (e.g., responding to a dirty bathroom as disgusting), but increased relational flexibility may be a desirable therapeutic outcome (e.g., not following the self-generated rule, "I must clean the entire bathroom every time a family member takes a shower").

Insensitivity to contingencies and persistent rule-following. Contextual behavioral scientists have frequently argued that rule-governed behavior and its role in generating insensitivity to direct contingencies of reinforcement may be implicated in human psychological suffering (e.g., McAuliffe, Hughes, & Barnes-Holmes, 2014). In addition, the human capacity to engage in derived relational responding has also been used to explain specific human maladaptive behaviors, such as irrational fears. To date, however, very little research has attempted to integrate research on contingency insensitivity and derived relations. Our research group recently conducted a study that has attempted to fill this gap and the interpretation of the results has been greatly facilitated by the MDML (Harte, Barnes-Holmes, Barnes-Holmes, & McEnteggart, 2017), and thus we will briefly consider this work here.

Across two experiments, participants received either a direct rule (Direct Rule Condition) or a rule that involved a novel derived relational response (Derived Rule Condition). Provision of a direct rule resulted in more persistent rule-following in the face of competing contingencies, but only when the opportunity to follow the reinforced rule beforehand was relatively protracted. Furthermore, only in the Direct Rule Condition were there significant correlations between rule compliance and stress. When viewed through the lens of the MDML, it appears that lower levels of derivation (Direct Rule Condition) may have produced more persistent rule-following than higher levels of derivation (Derived Rule Condition). That is, relational flexibility (in rule-following) may vary as a function of levels of derivation. Or more informally, we may “give up on a rule” more readily when it no longer works for us if the rule requires some recent derivation in terms of understanding its meaning.

However, the foregoing interpretation of the findings does not address the fact that levels of derivation appeared to have little impact on relational flexibility when exposure to the contingencies was relatively brief. Again, when viewed through the lens of the MDML, it could be argued that relational coherence may interact in a dynamic fashion with levels of derivation and relational flexibility. Or, more informally, participants may have been a great deal more certain that the rule was correct (i.e., coherent with the contingencies) when exposure to those contingencies was relatively protracted. If this interpretation is correct, then it suggests that the relationship between levels of derivation and relational flexibility (in rule-following) is moderated by levels of relational coherence. Or more precisely, level of derivation impacts more on relational flexibility when relational coherence is high rather than low.

As noted above, another finding arising from the study above was that lower levels of persistent rule-following predicted higher levels of stress, but only in the Direct Rule Condition with protracted exposure to the contingencies. An interpretation based on the MDML thus suggests that abandoning a rule when coherence is relatively high, and derivation is relatively low, may increase stress. Or more informally, the more participants felt they were disobeying a clear and well-established rule, the more stress they experienced.

If this interpretation is correct, perhaps increased relational flexibility (in rule-following), in the context of high coherence and low derivation, may come at the cost of increased stress levels. Or, in other words, disobeying a clear and well-established rule, even when it no longer works, creates greater stress.

Using the MDML to help us interpret the findings of this recent study also encouraged us to consider the implications of the findings for psychological suffering more generally. Insofar as persistent rule-following occurred when relational coherence was high and levels of derivation were low, it may be useful to consider the extent to which the assessment and treatment of depression, for instance, focuses on these variables. As a very brief and admittedly over-simplified example, when an individual presents in therapy as depressed, a therapist may explore the extent to which specific rules are being followed, which may undermine attempts at behavioral activation (e.g., ‘only exercise when you feel motivated’). More informally, this may involve discussing with the client how firmly they believe that such rules are indeed true or accurate (i.e., coherent) and how long they have been following them (i.e., level of derivation). Doing so may provide some insight into the potential reasons why a program of behavioral activation succeeds with one client but fails with another.

We recognize that the foregoing interpretation of the findings arising from our recent research, in terms of the MDML, remains highly speculative, but it does show how the framework is impacting upon our thinking and research activity more generally. And it provides another example of how the MDML may help to bridge the gap between basic RFT research and the clinical domain, similar to the clinical example provided toward the beginning of the current article.

Connecting RFT to the biological sciences with the MDML. Although highly speculative, it is possible that the levels of relational development specified in the MDML (e.g., from mutually entailing to framing to networking, etc.) may be correlated with different processing areas in the human prefrontal cortex (cf. Barnes & Hampson, 1997). For example, mutually entailing and relational framing abilities may be localized in the more posterior parts (see Barnes-Holmes, Staunton et al., 2005), with increasingly complex abilities, such as relating-relations, and relating relational networks, localized more in the anterior parts (see Barnes-Holmes, Regan et al., 2005). That is, increasingly complex AARRing abilities emerged as the neocortex evolved in modern humans (see Bickerton, 2007). Or to put it another way, the environmental and social contingencies selected increasingly sophisticated AARRing, and the necessary "underlying" cortical structures, because these advanced behaviors served to increase the survival of the species via enhanced cooperation and effective problem-solving.[8] Future brain-imaging studies could certainly test this hypothesis by scanning participants while they completed AARRing tasks at different levels of relational development as specified by the MDML. Confirmatory evidence would be consistent with recent arguments that AARRing did not evolve in whole cloth, but emerged gradually in humans because it served to support and enhance intra-group cooperative activities (Hayes & Sanford, 2014; Hayes, Sanford, & Chin, 2016).

Another potential line of research suggested by the MDML would be to determine if the location of the neural processing of AARRing shifts with changes in one or more of the dimensions and levels. Imagine, for example, a particular pattern of AARRing that is best categorized initially as an instance of relational networking. As the network is derived repeatedly, however, it might also reduce in complexity and thus it would be more appropriately categorized as an instance of relational framing or perhaps even mutual entailing. When this occurs, perhaps the location of the neural processing also shifts from the

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[8] What we suggest here is highly speculative and we are not arguing that the MDML, or even RFT itself, predicts or requires that increasingly complex AARRing abilities evolved with the human pre-frontal cortex. The evolution of human language and cognition is a highly complex area of research and will not likely yield to a simplistic analysis (see Hauser et al., 2014). Rather, we are highlighting one way in which the MDML framework may be used to explore possible areas of mutual interest between RFT researchers and those working in other areas of science.

anterior to the more posterior parts of the neocortex. Although wildly speculative, the MDML clearly suggests potentially fascinating lines of inquiry that could provide some depth to RFT research over the coming years. Indeed, it is worth noting that the MDML has recently been used to highlight possible areas of common research interest between RFT and cognitive neuroscience in the distinction that the latter has made between goal-directed and habitual behaviors (see Vahey, Bennett, & Whelan, in press).

Overview. Unfortunately, it is not possible to present all of the ways in which the MDML is opening up new avenues of thinking about and analyzing AARRing, and the potential it appears to have for building solid bridges between basic and applied research and practice, and indeed to other scientific traditions. Pursuing such issues will require numerous empirical studies and conceptual articles, to determine exactly how useful the MDML proves to be. However, we have come to a stage in its development where it seemed appropriate to share it with our colleagues in the hope that they too may find it to be of some use.

Conclusion

In closing, it seems fair to ask if what we have presented here is simply old wine in new bottles? In offering a new or novel framework for RFT, rather than a new or alternative theory, such a criticism could always be levelled at the MDML. The important issue from our perspective, however, is whether or not the MDML serves to stimulate new research questions and lines of inquiry that facilitate the reticulating model of science that contextual behavioral science sees as vitally important in generating vibrant and productive dialogue, research collaboration, and cooperation among basic and applied researchers, and practitioners, who reside both inside and outside of the contextual behavioral science tradition. If the MDML contributes in some meaningful way toward that overarching goal, then it will have served its purpose well.

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