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Hierarchical Classification from Relational Frame Theory: A Review

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Abstract

Hierarchical classification is of tremendous interest to both basic and applied research. This review explores hierarchical classification empirical studies from Relational Frame Theory (RFT). We identified 11 empirical articles that met inclusion criteria (demonstrated hierarchical responding in children or adults with an RFT theoretical approach). The objective of this qualitative systematic review is to offer both researchers and practitioners a solid and comprehensive view of types of protocols used from an RFT approach in establishing and analyzing hierarchical classification. Limitations and possible future research is discussed.
Key words: hierarchical relational responding, hierarchy containment classification, hierarchical classification, relational frame theory, transformation of functions, derived relations.

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Novelty and Significance

What is already known about the topic?

- Research on hierarchical responding from the RFT perspective is still very scarce.
- Hierarchical responding differs on conceptual and procedural level.

What this paper adds?

- This paper allows for the dissemination of knowledge about hierarchical responding from RFT point of view.
- This paper describes efficient training protocols to facilitate learning of this repertoire.

A typically developing child will be able to group animals according to different cues. For example, imagine that a child called Marcos is asked to group different animals based on how they move, he would create a group of flying animals (e.g., parrots, bats) and one of walking ones (e.g., dogs, lions). If one day Marcos was frightened by a bat in the darkness, he could later be frightened by other members of the flying category animals such as sparrows or pigeons. Now imagine that on another day, a friend of Marcos wanted to show him his new pet, a parrot. When Marcos asked his friend "what is a parrot?" and his friend answered "it is a colorful bird" Marcos probably could have shouted and asked his friend not to see his pet. Time goes by and Marcos likes other types of animals so much that he tells his parents he wants to be a veterinarian. Knowing how scared he is of animals with wings, his parents tell him that "a good veterinarian should save all types of animals". Sometime later, Marcos sees a sparrow with a broken wing in the street and despite his fear, he takes it home to try to save it.

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This is an example of the influence that categorizing behavior can have on our day-to-day lives. Hierarchical responding is a type of categorization in which the categories themselves are classified into a more generic one (Griffee & Dougher, 2002), as in the previous example. Marcos first does not like birds because they are part of the "flying animals" category but later, this category is in turn included in a more generic category "animals that a good veterinarian heals". This type of behavior is very flexible and contextually controlled, allowing humans to bring into categories all kinds of stimuli (even one´s own private experience) or grouping the same stimulus into an infinite number of categories (Bush, Sidman, & De Rose, 1989; De Rosse & Campos, 2010). This capacity would allow individuals to comprehend and learn from the constantly changing environment (Bruner, Goodnow & Austin, 1956).

Authors from different perspectives point out the importance of this type of behavior in various fields such as developmental, social behavior, educational, personality and clinical psychology. In more detail, studies from different theoretical accounts can be found related to intelligence, deductive-inductive reasoning, categorization and concept formation (Mandler, 2000; O'Hora *et alia*, 2008; Piaget, 1952; Rosch, Murphy & Medin, 1985; Vygotsky, 1934), categorization skills and the establishment of social behavior and prejudices (Hugenberg & Galen, 2004; Rhodes & Baron, 2019; Tajfel, 1982), personality and the construction of self-concept (Turner, 1985).

Most of the work that has been done on this topic has followed a cognitive perspective (Medin & Rips, 2005; Palmer, 2002; Piaget, 1952; Rosch *et alia*, 1976). The research in this field has tried to resolve questions about the age of acquisition of this repertoire (Piaget, 1952), the influence of perceptual similarities of the members of the category (Rosh, 1978), the distinction between the categories based on perceptual features and categories based on more abstract ones (Mandler, 2000; Piaget, 1952) and the neuropsychological components involved (e.g., Ashby & Waldron, 2000). Answers to these questions have been attempted mainly by following descriptive and correlational methods, mainly focussing on the developmental stages as the critical variable and understanding this behavior simply as a natural consequence of this development. Despite the advances that this approach brings, little has been clarified about what are the contextual variables susceptible to be manipulated that facilitate this response or the conditions under which the behavior is acquired (Barsalou, Simmons, Barbey, & Wilson, 2003; Medin & Rips, 2005; Palmer, 2002; Peraita, 1998).

Relational frame theory (RFT) following a behavioral-analytic approach, focuses on the study of the contextual variables and manipulations that are involved in the shaping of complex behaviors. From this perspective, complex aspects of human behavior typically denoted as language and cognition can be analyzed as a complex type of relational response denominated as Arbitrarily Applicable Relational Responding (AARR) (Hayes *et alia*, 2001). The AARR is conceptualized as a generalized operant result of the learning history in which stimuli that do not share any characteristics are related to each other. This response is characterized for showing three properties (Hayes *et alia*, 2001): *mutual entailment* (ME), *combinatorial entailment* (CE), and *transformation of stimulus functions* (TOF).

First, ME refers that if someone is taught a relation between two stimuli in one direction (e.g., A is the same as B) a derived relation appears in another direction (e.g., B is the same as A). Second, CE implies the combination of various relations (e.g If A is the same as B and B is the same as C, then A is the same as C. Finally, TOF) refers that the functions of one stimulus can be transferred to another stimuli by virtue of the derived relations between them (e.g., If A is cold then B is cold and C is cold). The type of the relations established between the stimuli determine the way in which these three properties occur. For example, if the relations established between the stimuli were based on opposition (A is trained to be the opposite of B and B is trained to be the opposite of C) the derived pattern of ME, CE and TOF would be different (e.g., B would be the opposite of A and C would be the same as A, A would be cold, B would be hot and C would be cold).

Basic research on RFT have shown well established evidence of relational frames like *coordination* (Barnes Holmes & Barnes-Holmes, 2009; Barnes-Holmes, Barnes-Holmes, & Murphy, 2014; Luciano *et alia*, 2007); *opposition* (Barnes-Holmes *et alia*, 2004); distinction (Dixon & Zlomke, 2005; Roche & Barnes, 1996); and *comparison* (Barnes-Holmes *et alia*, 2004; Berens & Hayes, 2007; Dunne *et alia*, 2014). However, the evidence on *temporal* (O'Hora, Barnes-Holmes, Roche, & Smeets, 2004; O'Hora, Peláez, & Barnes-Holmes, 2005; O'Hora *et alia*, 2008; O'Toole & Barnes-Holmes, 2009), *deictic* (Barnes-Holmes, 2001; Barnes-Holmes, Foody, Barnes-Holmes, & McHugh, 2011; McHugh, Barnes-Holmes, & Barnes-Holmes, 2004; Montoya Rodríguez, McHugh, & Molina Cobos, 2017) or *hierarchical* relations is not so extended (Gil *et alia*, 2012; Gil *et alia*, 2014; Kirsten & Steward, 2021; Ming *et alia*, 2017; Mulhern *et alia*, 2017, 2018; Slattery & Stewart, 2014; Stewart *et alia*, 2017; Zagrabska *et alia*, 2020).

Arbitrary Aplicable Hierarchical Responding is typically described as a frame in which a certain stimulus is in a "belonging to" or "being part" of relation with another one that "contain" or "includes" it. The pattern of derived relational responding in this frame typically is described as an asymmetrical ME and CE in which if A contains B and B contains C, C and B does not contain A. Rather, the relationship of C and B to A would be one of membership. Similarly, it is stated that the pattern of TOF is unidirectional from the higher-level stimuli (e.g., animals are multicellular) to the lower ones (e.g., rats are multicellular). A TOF that follows the opposite pattern, from the lower-level stimuli (e.g., rats have four legs) to the higher level one (e.g., animals have four legs) would be incoherent.

Although this response pattern is assumed in the literature to be as described above, basic research (later called analysis) in hierarchical responding is scarce and not all the evidence supports this analysis. For example, (Stewart *et alia*, 2017) tried to shape a hierarchical response that authors denote as parth-whole analysis in which the functions of the lower-level stimuli were also found in the higher-level ones. This would be useful to analyze hierarchical relationships in which the stimuli of the lower levels affect the higher ones, for instance companies that lose prestige due to the conduct of their employees.

Examples like the previous one show that the pattern of derived relational responding involved in hierarchical relations is quite complex. Through the analysis of the implemented procedures in the different studies that have attempted to bring hierarchical classification under contextual control, a better understanding of this relational response can be reached. Examining the possible discrepancies between the procedures used in different studies would allow us to not only comprehend the procedural and conceptual differences among the different studies but also to show whether the procedures at the basic level allow the different conceptual proposals to be maintained. This would help to clarify the status of the evidence provided at the basic level of the arbitrary applicable hierarchical responding.

This review describes the studies that from a contextual perspective aim to shape this response. The main issues addressed in this review are the relevant features implemented in the procedures to shape this response and the theoretical conceptualization of the hierarchical response that is intended to shape each study. The purpose of this review is to clarify the state of research in this area, examining the different procedures of the studies, to explain the differences between them and highlight the possible discrepancies between the basic analysis and the theoretical conceptualization. Systematic review seems to be an adequate method for the purpose of this article since it allows for a thorough and detailed comprehension of hierarchical responding conceptualization and procedures present in the selected studies.

Method

Search Procedure and Inclusion and Exclusion Criteria

A systematic review was made in July 2021 by the authors of this article in the following databases: Proquest (PsycArticles, Psycinfo, Psycbooks, Psyctest, ERIC y Mediline), Web of Science y Scopus. The keywords used were ("Hierarchical relational responding" OR "Hierarchical classification" OR "Class inclusion" OR "Hierarchy containment classification" OR "hierarchy") AND ("Relational frame theory" OR "Derived relations" OR "Transformation of functions" OR "Relational assessment"). These keywords were introduced in the same order in all the databases. The choice of keywords was decided to allow responding to the research question about different definitions and procedures of hierarchical responding in RFT literature. The search was completed by reference list review from the selected articles and expert opinion that is explained in more detail later.

The articles selected met the following inclusion criteria: a) peer-reviewed journal articles, b) empirical studies, c) all ages individuals with typical or atypical development, d) hierarchical responding e) RFT theoretical approach.

Results

Figure 1 shows the results yielded by the search in Proquest (PsycArticles, Psycinfo, Psycbooks, Psyctest, ERIC y Medline), Web of Science and Scopus. A total of 232 were retrieved. After discounting the duplicates, 216 remain and of these, 154 were discarded after reviewing the titles and the abstracts; these were not related with the purpose of the study or did not meet the inclusion criteria. The remaining 62 articles

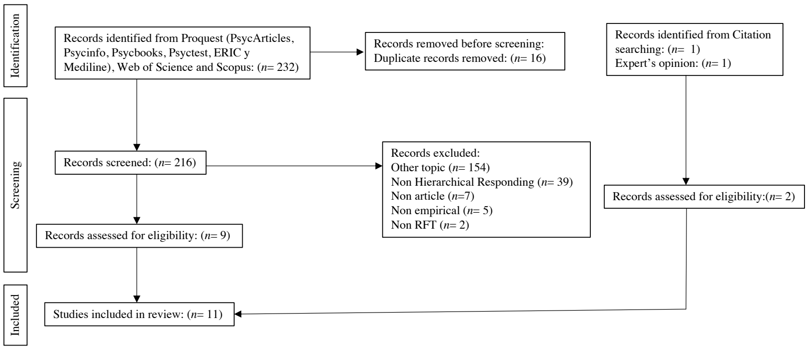

Figure 1. PRISMA flow diagram of the selection of studies.

were full-text reviewed to assess the inclusion criteria. Of these, 39 were excluded for non-hierarchical responding, 7 were excluded for non article, 5 as non empirical, 2 were excluded for non-RFT theoretical approach, in total 9 articles were selected. First paper (Griffe & Dougher, 2002) was incorporated after being in the reference list of one of the selected article (Slattery & Stewart, 2011) and the last one (Kirsten & Stewart, 2021) because of its relevance for this review confirmed by an expert opinion (third author of this review). Finally a total of 11 papers were included.

The eleven selected articles were published in relevant journals for the area of study. The studies were divided in two main lines of research: a) *Analyzing hierarchical responding*, studies focused on making preparations to bring and test hierarchical response in laboratory settings involving adults who already possess this repertoire; and b) *Training hierarchical responding*, studies focused on assessing and training hierarchical response with typically and non-typically developing children lacking this repertoire or in need of improving it.

The articles were coded according to the following characteristics: 1) Author, year of publication; 2) sample (number of participants, age, population); 3) analysis/ training; 4) definitions; 5) procedures; 6) results; and 7) conclusions.

The *Analyzing* line was composed of six articles and was divided in two categories: two precursors studies, where the approach is mainly based on classic behavioral principles (Griffe & Dougher, 2002; Slattery *et alia*, 2011); and four RFT studies that attempt to conceptualize hierarchical response taking an RFT perspective (Gil *et alia*, 2012; Gil *et alia*, 2014; Slattery & Stewart, 2014; Stewart *et alia*, 2017).

Regarding the precursor studies, Griffe and Dougher (2002), attempted to produce a hierarchical categorization response in a laboratory setting analogous to the categorization behavior that takes place in natural language. In more detail authors define hierarchical categories as stimuli that share common physical characteristics but are generally categorized according to their function as in an example of the cats with different fur length that can be categorized as being the same (e.g., they are all cats and not dogs). However, in other contexts it is useful to differentiate between short-haired cats and long-haired ones.

The procedure was as follows, a contextually controled discrimination training which consisted mainly of training relations between 4 triangles (cats) that varied in the angulation from more obtuse to more acute (S3, S6, S9, S12 from long haired to short haired cats) three color contexts (green, red and yellow) and seven option choices (R1, R2...R7) used to train a differential response. The triangles appear on the top of the screen one at a time while the seven option choices appear at the bottom and both in the presence of a color background that sets the context. The green context sets the most general response ("they are all cats"), participants earn 6 points to choose R4 in the presence of any triangle. The red context sets an intermediate one ("some are long-haired and others short-haired cats) participants earn 6 points to choose R1 in the presence of S3 or S6 and R7 in the presence of S9 or S12 and 3 points to choose R4 in the presence of any triangle. Finally, the yellow context sets the most specific response ("each cat has its own name") participants earn 6 point to choose R2 in the presence of S3, R3 in the presence of S6, R5 in the presence of S9 and R6 in the presence of S12, 3 point to choose R1 in the presence of S3 o4 S6 and R7 in the presence of S9 and S12, and 1 point to choose R4 in the presence of any of them. This training doesn't seek to arbitrarily relate the stimuli of the different levels of the category but is based on training a response based on physical properties (triangles). The following studies would aim for training of stimuli with arbitrary stimuli.

Table 1. Characteristics of the studies selected.

Study	Participants	Type	Definitions	Procedures	Results	Conclusions
Grieffe & Dougher (2002)	5 adults	Analysis	Contextual control of functional classes	Discrimination training, generalization and equivalence processes	All participants showed generalization test and symmetrical responding. 4/5 showed transitivity test	First attempt to model hierarchical categorization from an experimental analysis perspective. Hierarchical categorization through the contextual control of functional classes established by processes of conditional discrimination and generalization of stimuli. Extension of hierarchical functional classes by arbitrarily related verbal stimuli
Slattery *et alia* (2011)	1st exp: 5 adults 2nd exp: 3 adults 3rd exp: 3 adults	Analysis	Contextual control of functional classes	Discrimination training, generalization and equivalence processes.	In the 1st and 2nd experiment participants showed conditional discrimination training and generalization test but didn't show transitive class containment. In the 3rd experiment participants passed all the tests	Improvement of Grieffe *et alia* (2002) procedure. Testing transitive class containment achieved by training with graduated arbitrary stimuli
Gil *et alia* (2012)	10 adults	Analysis	RFT. General type of hierarchy.	Nonarbitrary Containment and Arbitrary Hierarchy	9/10 participants passed the test by combinatorial (transitive) and derived relations. Bidirectional TOF	First to use arbitrary stimuli as hierarchical relational cues, to train the networks using these cues and to test transformation of functions in accordance with hierarchical relations
Slattery & Steward (2014)	1st exp: 4 adults 2nd exp: 6 adults	Analysis	RFT. Type of a hierarchy: Class-Member	Nonarbitrary Containment and Arbitrary Hierarchy	1st Experiment: all participants showed mutual and combinatorial relations. 2nd Experiment: all participants showed mutual and combinatorial relations	Modeling hierarchical classification from RFT perspective and testing asymmetrical and transitive class containment and unilateral property induction
Gil *et alia* (2014)	8 adults	Analysis	RFT. General type of hierarchy	Nonarbitrary Containment and Arbitrary Hierarchy	5/8 participants passed the test by combinatorial (transitive) and derived relations. Bidirectional TOF	Improvement of *Gil et alia* (2012) protocol. Demonstration of bidirectional TOF (bilateral property inductions) according to hierarchical relations by training the relations in one direction and by including the sentence "part of"
Stewart *et alia* (2017)	10 adults	Analysis	RFT. Type of a hierarchy: Part-Whole	Nonarbitrary Containment & Hierarchy	All participants showed mutual and combinatorial responding. Different patterns of TOF were shown. Bidirectional TOF.	Modeling hierarchical analysis from RFT perspective and testing asymmetrical and transitive class containment and bilateral property induction. Importance of nonarbitrary training

Notes: ASD= Autism Syndrome Diagnosis; RFT= Relational frame Theory; TOF= transformation of functions.

Table 1. Characteristics of the articles included in the review that demonstrated hierarchical responding in children or adults (cont.).

Study	Participants	Type	Definitions	Procedures	Results	Conclusions
Mulhern *et alia* (2017)	50 children ages 3-8	Training	RFT. Hierarchy based on nonarbitrary/arbitrary containment and arbitrary hierarchy	RFT. Hierarchy based on nonarbitrary/arbitrary containment and arbitrary hierarchy	Age trend in acquisition of relational framing. The 3-4 years didn't show relational repertoire capacity. 7-8 years old showed nonarbitrary and arbitrary repertoire capacity (mutual, combinatorial y TOF) but not arbitrary hierarchy. Correlations between acquisition of relational framing and cognitive and linguistic tests	Proves benefit of training in relational frames of categorization, considering how it´s correlated to the IQ, language development and CI tasks and test-retest results. Strong correlations between relational framing and performance on standardized intellectual cognitive and linguistic measures
Ming *et alia* (2017)	3 children (ages 3-4) 3 children ASD (ages 8-19).	Training	RFT. Hierarchy based on nonarbitrary containment and comparison	Nonarbitrary Containment and Arbitrary Hierarchy	Typically developing participants met criteria (class inclusion responding and demonstrated generalization and maintenance) in 3-7 sessions. The ASD participants met the criteria after 10-16 sessions	First study to use an RFT based approach to teach class inclusion based on nonarbitrary relational responding with typically developing and ASD spectrum disorder participants
Mulhern *et alia* (2018)	1st exp: 6 children ages 5-6. 2nd exp: 6 children ages 6-7	Training	RFT. Hierarchy based on nonarbitrary/arbitrary containment and arbitrary hierarchy	Nonarbitrary Containment and Arbitrary Containment and Arbitrary Hierarchy	1st experiment: experimental group participants showed generalization and maintenance in nonarbitrary and arbitrary containment (mutual, combinatorial and TOF). 2nd experiment**:** experimental group participants showed generalization and maintenance in arbitrary hierarchy (mutual, combinatorial and TOF)	New protocols of training repertoire of relational framing through multiple-exemplar- training (MET)
Zagrabska *et alia* (2020)	3 adults ASD	Training	RFT. Hierarchy based on nonarbitrary containment and comparison	Nonarbitrary Containment and Arbitrary Hierarchy	All participants met the criteria (class inclusion responding and demonstrated generalization and maintenance) between 2-5 weeks and (6-15 sessions)	Extension of Ming *et alia* (2018) protocol. IQ training with ASD participants. Response contingent feedback in the baseline was insufficient to train the relational pattern but the contingent feedback and prompts centered around nonarbitrary relations were sufficient to train the repertoire
Kirsten & Steward (2021)	24 children ages 36-84 months	Training	RFT. Hierarchy based on nonarbitrary/arbitrary containment and arbitrary hierarchy	Nonarbitrary Containment and Arbitrary Containment Arbitrary Hierarchy	Relational assessment results depended on age showing patterns of development related to nonarbitrary vs arbitrary and type of the frame studied: coordination, comparison, opposition, temporality and hierarchy. Emergence of comparative and hierarchical relational performance improves in agse 4-5 and 5-6, also comparison and hierarchical relations are strongly correlated with IQ results	Cross-sectional assessment of the acquisition of frames in young kids with a new REP procedure. Evidence for the relevance of relational framing across ages, it´s correlation with IQ and certain patterns of relational framing have been observed

Notes: ASD= Autism Syndrome Diagnosis; exp= experiment; IQ Intelligenzquotient; RFT= Relational frame Theory; TOF= transformation of functions.

After this training phase, a generalization test was carried out that consisted of presenting novel triangles (varied from more acute to more obtuse) maintaining the same response options and color context as in the training phase. The test aimed to prove if the trained responses were generalized to novel stimuli that share features with those of the training phase (triangles). The second part of the experiment started with a training phase quite similar to the first one. However, in this case the option choices were 7 nonsense syllables ("wug" instead of "R4", "yap" and "zig" instead of R1 and R7 consecutively, and "git", "bup", "gak" and "pif" instead of R2, R3, R5 and R6 consecutively). The reinforcement contingencies were identical to those of the first part.

After the training phase tests were carried out, that mainly consisted of the transitivity test and the generalized symmetry test. The generalization test was identical to that of the first part but was using the nonsense syllables instead of the option choices. The transitivity test consisted of presenting the nonsense syllables on the top of the screen one at a time across all the color backgrounds while participants had to select one of the option choices at the bottom of the screen. The purpose was to assess whether the original stimulus function trained in part 1 (option choices) would transfer to the nonsense syllables. Finally, the generalized symmetry test consisted of presenting the triangle on the screen and just below the triangle one of the nonsense syllables and the words yes or not. The purpose was to evaluate the untrained symmetric relationships between the nonsense syllables and the new triangles.

The results showed that all the participants answered the tests correctly, showing a response consistent with hierarchical categorization in a natural language as authors define it (where depending on a context [green, red or yellow] triangles [cats] are either considered as same or different based on their characteristics). Therefore, hierarchical categorization was established by two processes: conditional discrimination and stimuli generalization.

According to Slattery *et alia* (2011), participants in Griffe and Dougher (2002) showed a response consistent with the transitive class containment (TCC), but it was not explicitly evaluated. Therefore Slattery et alia (2011) replicates the previous study including some changes in the procedure and test for transitive class containment (TCC), which indicates that if A is the member of B and B is the member of C, then A is the member of C. TCC is one of the three core features of hierarchical categorization according to cognitive conceptualizations (e.g., "apple" belongs to a category "fruits'' and "fruits'' belongs to a category "food" allows to derive that "apple" belongs to "food" as well. The remaining two are known as asymmetrical class containment (ACC), that indicates that if class A contains class B, then class B can't contain class A (e.g., "food" contains "fruits'' and "dairy" but "fruits'' does not contain "food'') and unilateral property induction (UPI) that indicate that the properties from the top of the class should be shared by all the members while those from the bottom of hierarchy are not necessarily shared by all the members of the class (e.g., all food is "eatable" although not all food is "sweet") (e.g., Murphy, 2002). The study includes three experiments. In the first one, Slattery *et alia* (2011) replicated Griffe and Dougher (2002) study and introduced a new test where novel stimuli were presented to test transitive class containment (TCC). 2 out of 5 participants demonstrated such responding. In the second experiment the authors were trying to determine whether additional training could facilitate such responding. None of the participants passed the transitive class containment test. Finally in the third experiment, multiple exposure to abstract or arbitrary stimuli is used to enhance this process. The main difference in the training consisted of gradual substitution of original triangle stimuli into abstract arbitrary stimuli. All participants passed the transitive containment test.

This series of studies replicates Griffe and Dougher (2002) results and show transitive class containment although it is not impossible that the results could be explained by a generalized color- background controlled second-order conditional discriminative responding. This response was achieved by introducing gradual arbitrary stimuli. These studies advance on comprehension of categories in which stimuli can be organized based on common physical characteristics but are generally categorized according to their function and not more abstract ones. The studies from the contextual behavioral approach reviewed above have advanced the study of how categorization can be brought under contextual control under laboratory conditions based on three main ingredients: discrimination, generalization and equivalence. There is no hierarchical relations training per se nor testing of transformation of the functions.

The RFT studies argue that this type of relational response has its origins in multiple-exemplar-training (MET), based on the non-arbitrary relations of inclusion (or containing) and belonging to (or members of). Therefore an experimental analog of this training is intended, where abstract relational cues of inclusion (or containing) and belonging to (or members of) are formed and later used to relate any type of stimuli.

Gil *et alia* (2012) is the first experiment that is aiming to train relational cues (i.e., "includes'' or "contains" and "belongs to" or "is member") in order to train hierarchical categories and test transformation of functions from RFT perspective. In this series of experiments, no conceptual analysis is offered prior to the description of the experiments, only examples of very general models of hierarchies are presented like in the following example. "María tells her friend Juan that her family is visiting soon. One part of her family is from Santander and is very intelligent, while the other part of her family is from Sevilla and is very funny. Next, Juan meets María's cousin from Sevilla (Ana) and her uncle from Santander (Luis). Juan automatically assumes that Ana will be funny, and Luis will be intelligent. In sum, if Juan is asked about María's family, he will respond that her family is funny and intelligent or, more precisely, that one part is funny and the other part is intelligent" (Gil *et alia*, 2012, p.3).

In more detail, the procedure was composed of five phases. In Phase 1 four arbitrary stimuli were established as contextual cues ("Includes", "Belongs to", "Same" and "Different") through multiple exemplar training. MET is a type of training where bidirectional reinforcement is allowing for the emergence of a type of generalized relational behavior (Hayes *et alia*, 2001). In this part of the study stimuli were mostly based on pre-experimental functions (pictures of faces and its elements- nose; and categories already existing, like: hospital and its parts, e.g., nurse) which might have affected the isolation of the relevant functions to establish the hierarchical cues.

In Phase 2 two networks consisting of three four-member equivalence classes were established using the "Same" cue (A1-B1-C1-D1, A2…D2), which would be the lower levels of the hierarchical network. In Phase 3 middle and top levels of hierarchical categories were established using hierarchical cues (INCLUDES and BELONGS TO). Three novel stimuli (X.1, X.2 and Y.1, the middle of the hierarchies) were related with some stimuli of the equivalence classes (the bottom of the hierarchies). Later the top-middle of the hierarchies were trained in the same way, relating the X.1, X.2 and Y.1 stimuli with two novel ones (X and Y, the top of the hierarchies). In Phase 4 functions were given to three stimuli at different level networks using the words "is always". In Phase 5 (Critical Test) six stimuli from the networks were tested for transformation of functions. 9/10 participants showed a pattern of response compatible with TOF in accordance with the type of hierarchical network trained in the study. Using the words “Is always” may have excessively facilitated TOF, also hierarchical relations were trained in both directions therefore not allowing to isolate derived relations. Note that the relevant aspect of the procedure is the way in which the contextual cues are trained, mainly based on day-to-day stimuli relations which possibly could determine the pattern of TOF that would be bidirectional.

In the following study, Gil *et alia* (2014) replicated and improved the findings described above and overcame its several limitations. Although the training of relational cues was still based on pre-experimental functions that might have affected the isolation of the relevant functions to establish the hierarchical cues. Same as in the previous study the TOF was bidirectional showing that functions might transfer bottom- up from lower level to higher level of the hierarchy. Again, performance of TOF could have been affected, in this experiment by using words “it is” and “it has a part” used during the training and testing. The findings constituted a more robust demonstration of the transformation of stimulus functions according to hierarchical relations (Gil *et alia*, 2014).

The two studies reviewed above have advanced on the study of the use of arbitrary stimuli as hierarchical relational cues, also on training the networks using these cues and on testing transformation of functions in accordance with hierarchical relations. Those studies made progress in the use of different relational cues, not just “Includes” and “Belongs” but also “Different” and “Same” allowing for a better control over establishment of the functions.

Two last studies in Analysis line (Slattery & Stewart, 2014; Stewart, 2017) would model properties of hierarchical classification in two different models and conceptual approach: “member-class” (i.e., responding to “members” as being contained in “classes”) and “part-whole” (e.g., responding to “parts” as being contained in “classes”). Slattery & Stewart (2014) aimed to model a “member-class” (class-concept) hierarchy following cognitive developmental research (e.g., Markman & Seibert, 1976) aiming to prove three core features: TCC, ACC and UPI. It is expected that these different conceptual approaches would result in different patterns of TOF.

Training of relational cues was based on non-arbitrary stimuli where participants responded to stimuli as part of a collective based on shared features (i.e., a class of which they are members). The difference from previous experiments was that it was mostly based on day-to-day relations and here it´s based on nonarbitrary stimuli. There were two experiments. In the Phase 1 of the first experiment authors used two arbitrary shapes as contextual cues for “Member of ‘’ and “Includes’’ by training subjects in responding to multidimensional shape stimuli that were nonarbitrarily interrelated along particular physical dimensions (color, shape or same number of dots inside the shapes) so they could be responded as individual stimuli but also as “classes’’ (two blue objects, three blue squares, five dots inside different shapes). New stimulus sets were included to guarantee appropriate contextual control with and without feedback. The contextual cues were trained based on abstraction of common physical properties (“classes”) and examples of shapes with these properties (“members”).

In the Phase 2 contextual cues for “Member of” and “Includes” were used to establish arbitrary hierarchical relations by relating novel trigrams (H1, H1.1., H1.1.1 and H2, H2.1, H2.1.1) with contextual cues in the presence of feedback. Later an arbitrary relational responding test (ME and CE) was carried out. Stimulus function training by an MTS procedure was used to establish for two of the stimuli (H1.1 and H2.1- intermediate level of networks) where the H1.1- “has’’ grey flecks (F1) and H2.1- “has’’ blue spikes (F2). Finally, transformation of functions was tested on different levels of the network (H1, H1.1, H1.1.1, H2, H2.1, H2.1.1) where it was expected that F1 would transfer from H1.1 to H1.1.1 (UPI) but not to H1 (since H1 is a superordinate class). All participants showed all three properties: transitive class containment, asymmetrical class containment and unilateral property induction.

The nonarbitrary training used very simple stimuli that shared the same manifestation (e.g., spots or dots), while in real life often stimuli that are related differ significantly. To solve this, the procedure of the second experiment included training of nonarbitrary stimuli that were less physically similar. The pattern of response present in Experiment 1 was largely reproduced. Although a small number of participants didn´t show a unidirectional pattern of TOF (top-down).

In the second study, Stewart *et alia* (2017) modeled a second type of categorization which they named hierarchical analyses (collection-concept). The main difference with the “member-class” conceptualization is that in this case the relations among the stimuli are based on “part-whole” relations. For instance, a hand (whole) is composed of fingers (several parts). Authors argue that while in the “member-class” conceptualization the transformation of functions is unidirectional, in “part-whole” hierarchies these transformations could be bidirectional.

In more detail in the latter study, in the Phase 1 the contextual cues were trained based on abstraction of common physical properties (“classes”) and examples of shapes with these properties (“members”). In the current study, the relations between shapes were made up of a number of different parts (“wholes”) and examples of the parts themselves (“parts”). For example, “part” would be a blue triangle and a “whole” would be a compound of a blue triangle, green rhombus and a pink arc. New stimulus sets were included to guarantee appropriate contextual control with and without feedback. The relations between shapes were made up of a number of different parts (“wholes”) and examples of the parts themselves (“parts’’). The Phase 2 was very similar to the previous experiment (Slattery & Stewart, 2014). Finally, transformation of functions was tested on different levels of the network (H1, H1.1, H1.1.1, H2, H2.1, H2.1.1) where it was not clear what type of TOF might predominate. The pattern of TOF in this study was different, only one participant showed unidirectional top down, while the remaining showed: 4 bidirectional, 2 unidirectional bottom-top and one was inconsistent. Authors indicate that it could be due to the different type of hierarchical relational responding (analytical vs clasificative). It is possible that using proximity as a defining element of the part-whole relation could cause that other features might support the emergence of part-whole relationship and possibly facilitate the TOF pattern.

The two studies reviewed above have advanced on defining different types of hierarchical relational responding (“class concept” vs “collection-concept”) and modeled properties of hierarchical classification according to the cognitive literature, namely, transitive class containment, asymmetrical class containment and unilateral and bilateral property induction. There is an advancement in training of relational cues based on either common properties or proximity.

All the studies from the RFT research line reviewed above have advanced the study on hierarchical categorization although with numerous limitations as type of definition of hierarchical relational responding, different training of relational cues and different testing procedures. First two studies aimed to model a general type of hierarchical responding while the latter two ones aimed to model two different types of hierarchy (member-class vs part-whole), also procedures differed significantly. More analysis about that topic would be offered in the Discussion.

The Training of Hierarchical Relations line includes five articles (second part of the Table 1) which have been classified in two categories: a) The *class inclusion* (Ming *et alia*, 2018; Zagrabska & Ming, 2020) includes studies that purpose is to train how to respond to a class inclusion task (CI) in typical and atypical developing children. CI is usually used in cognitive research that is related to classification and categorisation repertoires (Piaget, 1952); and b) *Patterns of relational framing* (Mulhern *et alia*, 2017; Mulhern *et alia*, 2018; Kirsten & Steward, 2021) consist of studies that focus on assessing and training relational framing in typically developing kids.

In the class inclusion line initiated by Ming *et alia* (2018) authors aim to assess and train class inclusion tasks with an RFT approach for typically and non-typically developing children. CI tasks require responding to one stimulus as a member of simultaneously two categories, where one is more inclusive than the other ("Yorkshire terrier" is a member of the category "dog" [less inclusive] and "dog" is a member of a category "animal" -more inclusive). The authors argue that hierarchical relations are based on simpler relations of containment, comparison and a combination of those in the context of categories and are aiming to train subjects in these relations to enhance CI task responding.

Three typically developing children and 3 with autism spectrum disorder diagnosis were first screened to ensure that they can: tact stimuli, answer yes/no (e.g., "is this a cat?"), tact the category of all stimuli (e.g., "What category does this [picture of a cat] belong to?" "Animals"), tact quantities from 1-10 and answer quantity comparison questions (e.g., "Are there more cats or more dogs?"). Following this, participants were preassigned to the baseline phase with different lengths (three, five, or seven sessions) which consists of application of the class inclusion task. The baseline consisted of CI training that included answering 16 trials of 8-intercepted questions (i.e., questions that use more or less; "Are there less dogs or less cats?") and 8 inclusion class questions (i.e., from 4 categories, 6 objects each; "Are there less animals or less cats?"), nonspecific praise ("You are working very hard") was provided for all trials and scheduled noncontingent reinforcement (on the schedule identified by teacher).

The intervention phase (Phases 1 & 2) was based on a multiple example training provided (using nested boxes and flashcards) with the purpose of promoting the abstraction of the "containment" (in/out) relationship of the smaller category within the larger one. Specifically, in Phase 1 (pretrial prompting) participants were instructed about the specific stimuli (animals) that were used in the trial (e.g., three cats, six horses) and belonged to the animal category and box (e.g., "Cats and horses are both animals''). Later they were asked to put flashcards (concrete animal stimuli) into the correct plastic boxes and to place the smaller boxes inside the large box. Feedback was given (repeating "You got it, there are less horses than animals!") while physically lifting up relevant boxes (with all the animals and the horses separately). Incorrect responses were followed by repeating the requirement to select the stimulus type and category boxes with detailed feedback until the participant responded correctly to the first trial with new stimuli. This part of training is based on training containment and comparison relational cues.

In Phase 2 (reduced prompting) non selection of boxes was asked, feedback was reduced to eliminate explicit reference to the size of the boxes (big, small). The intervention was continued until the participant responded correctly on each of the eight class inclusion trials. In Post Intervention probes when participants reached the criterion for the Intervention, the same procedures as in baseline were used to assess generalization (animals and four category types interspersed). Maintenance was assessed. Results show that typically developing subjects met criteria (class inclusion responding and demonstrated generalization and maintenance) in 3-7 sessions. The ASD subjects met the criteria after 10-16 sessions.

In the following study, Zagrabska & Ming (2020) extended Ming *et alia* (2018) protocol to evaluate if response-contingent feedback and reduced prompting would be sufficient to train class inclusion (CI) in three adult ASD participants. The current study differs from the former in the use of response-contingent feedback and pretrial prompting. In the former in the baseline the feedback was non-contingent while in the current the feedback is contingent. In the former in the Intervention Phase 1 of pretrial prompting was delivered while in the current study it was omitted. Finally, generalization and maintenance were tested 2 weeks after the end of testing. All participants met the criteria (class inclusion responding and demonstrated generalization and maintenance) between 2-5 weeks (6-15 sessions).

In many previous studies provisions of contingent feedback allowed for the acquisition of the relational operant but in this experiment response contingent feedback (depending if they responded correctly or wrongly) in the baseline was insufficient to train the relational pattern. While the less intrusive (compared to Ming *et alia*, 2018) intervention contingent feedback and prompts centered around nonarbitrary relations in Phase 2 were enough for class inclusion responding. Nonarbitrary training is essential to the intervention.

The class inclusion lines have advanced on teaching class inclusion based on nonarbitrary relational responding (containment and comparison) with typically developing and ASD spectrum disorder participants.

The second line of research, Patterns of relational framing initiated by Mulhern and Stewart (2017) aimed to assess and train relational framing related to categorization in typically developing kids and correlate them with linguistic and cognitive potential.

The authors design a protocol to assess hierarchical classification based on the previous studies (e.g., Gil *et alia*, 2012; Slattery & Stewart, 2014). The protocol was composed of several response repertories from simple to abstract non-arbitrary containment, arbitrary containment and arbitrary hierarchy.

Fifty typically developing children (23 female) between 3-8 years of age participated in the experiment and were exposed to a number of different assessments: Colour Tacting, Yes-No responding. The Relational Responding Test 1 had three parts (repertoire), each one of them was trained in a separate session (40-45 minutes). In the first one *nonarbitrary containment* was measured by presenting different stimuli (boxes of different sizes and colors) and demonstrating the relationship between them verbally or physically (e.g., "A red box is inside a blue box" so "Is the red box inside a blue box?"). Lastly questions were asked about the relationship between stimuli. In the second one, *arbitrary containment* was measured similarly: Stimuli were presented (same sized triangles and circles, different colors) but the relations are described verbally without a demonstration, also because the exact same size of stimuli wouldn't allow for demonstration of any physical relations between them, therefore promoting arbitrary relating. After showing the stimuli, questions were asked about the relationship between stimuli (e.g., "The red circle is inside the blue circle" so "Is the red circle inside the blue circle?"). In the third one arbitrary hierarchy was measured by stimuli being presented on a computer screen and questions were asked about arbitrary derived relations (e.g., "A tol is a type of animal" so "Is a tol a type of animal? Is an animal a type of tol?").

The authors aimed to study different relational framing repertoires, from nonarbitrary containment (concrete and simple), through arbitrary containment (more abstract and complex) to the arbitrary hierarchy (abstract and complex). They expect that if a child is taught to put one object inside another (nonarbitrary containment) accompanied by cues as "in'' or "inside", then it would allow them to lay foundation for more abstract patterns of responding like (arbitrary containment) where the stimuli are not in physical relation of containment. Later they are expected to be able to respond to even more complex relations (arbitrary hierarchy) where just by establishing verbally some relations between stimuli, they should derive further relations. Later, numerous tests were administered: SB5- intelligence test, PPVT-4-receptive vocabulary test, CCT-categorization skills for children, Piagetian CI-class inclusion test and Relational Responding Test 2 same as Relational Responding Test 1.

Relational Framing per age cohort demonstrates a development trend in acquisition of relational framing repertoire. The 3-4 years old children showed almost no capacity in the three specific relational repertoires assessed. The oldest group (7-8 years old children) showed the emergence of the three repertoires: nonarbitrary containment (ME, CE) arbitrary containment (ME) and the slow emergence of the rest of the tested repertoire. The arbitrary hierarchy repertoire was still very poorly developed. There are high test-retest correlations in Relational Responding Tests (nonarbitrary containment, arbitrary containment, arbitrary hierarchy). Also, a correlation between acquisition of relational framing and cognitive and linguistic tests was observed.

In the following article Mulhern *et alia* (2018) aimed to extend Mulhern *et alia* (2017) protocol, to assess and train relational framing in young typically developing children and measure the impact of this training on language and categorization skills. Two experiments were conducted. In the first one, arbitrary containment was trained and in the second one arbitrary hierarchy. In the first experiment 6 typically developing kids (age 5-6) were assessed before training intervention using: PPVT-4-receptive vocabulary test, CCT-categorization skills for children, Piagetian CI-class inclusion test and non-arbitrary and arbitrary containment. Inclusion criteria were passing the non-arbitrary containment test but failing in the arbitrary containment one. Participants were randomly assigned to experimental (3) or control group (3). The study employed a combined multiple baseline design. After establishing a baseline (until a stable level of responding was observed), non-arbitrary containment and arbitrary containment were assessed with procedures analogous to Mulhern & Stewart (2017) but in the current experiment with no feedback and no reinforcement. Transformation of function through ME and CE in non-arbitrary, arbitrary containment and arbitrary hierarchy was tested.

In the training phase participants were exposed to arbitrary containment relational training over multiple weeks, while each session lasted for 40 minutes and was held five times per week. The training was the same as assessment (e.g., "A is inside B" so "Is A inside B?") with a difference in providing scheduled contingent feedback in trials, promising prizes for achieving goals for each session and each session trying to beat the previous result to receive an additional prize. Generalization and maintenance were evaluated. All participants were successfully trained in arbitrary containment.

In the second experiment 6 typically developing kids (age 6-7) were exposed to the same experimental design as Experiment 1 except for assessing arbitrary hierarchy (no feedback) where participants have been presented stimuli on the screen and the experimenter inquired about relationships established between stimuli with a yes and no responses. 3 participants were randomly assigned to the training group and 3 others were assigned to the non-training group. In the training phase participants were exposed to the arbitrary hierarchy training (e.g., stimuli being presented on the screen and questions being asked like: "A tol is a type of animal" so " Is a tol a type of animal? Is an animal a type of tol?") over weeks. All the contingencies involved were identical to those of the previous experiment. Results showed successful generalization and maintenance of the arbitrary hierarchy. This experiment offered further evidence of efficacy of RFT-based interventions to establish derived relational responding repertoire in young children.

In the final study Kirsten & Stewart (2021) investigated the normative development of relational framing in childhood (coordination, comparison, opposition, temporality, and hierarchy) and analogical responding in young children (3 to 7 years old) against standardized tests of cognitive abilities. Authors based on previous research in both areas: relational framing (McHugh *et alia*, 2004; Mulhern *et alia*, 2017) and analogy (Barnes *et alia*, 1997; Carpentier, 2002, 2003; Cassidy *et alia,* 2011, 2016; Hayes & Stewart, 2016) decided to research with the use of MET and relational evaluation procedure (REP).

Twenty-four children of typical development (14 females) from 36 to 84 months old participated in the study. Standford-Binet Intelligence Scales-5th Edition for Early Childhood and Relational Assessment (without feedback but with a pretrial per each stage (examples), the latter in four stages (type of relations) were administered. In Stage 1 nonarbitrary (physical) relations were assessed (bigger or smaller objects) in Stage 2 nonarbitrary analogical relations (relations between physical relations) were assessed, in Stage 3 arbitrary (abstract) relations were assessed; in Stage 4: arbitrary analogical relations (relations between abstract relations) were assessed. Later arbitrary and nonarbitrary relations of coordination, comparison, opposition, temporality and hierarchy were evaluated.

Since for the authors of this article hierarchical relations are of most interest, a more detailed description of this frame is described. In Stage 1 hierarchy is assessed by presenting trials with two or three different sized and colored boxes and the following questions were asked: "Which one is inside? Which one contains the other one? Does x contain y? Is x inside y?" In Stage 2 each trial included a sample and comparison of stimuli like one square inside another square and small dots located in either the innermost or outermost square or outside the squares. The following questions were used: "Which one of these (points to comparisons) is like the one at the top (points to sample)"? In stage 3 the stimuli were simple black and white shapes separated by a letter indicating contextual cue plus corresponding audio icons. The following questions were asked: "Is x inside y? Does x contain y?" In stage 4 REP (Relational Evaluation Procedure) procedure was being used with black and white circles were being used plus visual and audio signals (for non-literate participants) representing the contextual cues. Results showed dependent on age patterns of development related to nonarbitrary vs arbitrary relations of all the frames studied: coordination, comparison, opposition, temporality & hierarchy. The emergence of comparative and hierarchical relational performance improves at ages 4-5 and 5-6, also comparison and hierarchical relations are strongly correlated with IQ results.

This study offers further advancement in comprehension of emergence of different frames and its relevance to enhance design of programs that would allow more efficient training protocols. Hierarchical frame is based on the nonarbitary and arbitrary containment but also comparison, which proved to be an efficient design protocole in Ming *et alia* (2018) and Zagrabska & Ming (2020).

The Patterns of relational framing research line have advanced on measuring patterns of relational framing related to categorization in typically developing kids and correlate them with linguistic and cognitive potential. The studies from the analysis line reviewed above have advanced on comprehension and training of relational framing used either for CI tasks or relational framing tests in typical and non-typical developing participants.

Discussion

This review shows the status of the evidence in training and analyzing hierarchical responding from an RFT perspective conceptualized as a type of arbitrarily applicable relational responding. Two main points regarding the studies are discussed, the definitions and experimental procedures. Even if research in this article is based on the same theoretical principles, when carefully analyzed it proves to be different both on conceptual and procedural levels. Differences regarding the Analysis and Training line of research were described.

Regarding the Analysis line, in the precursor studies, Griffe and Dougher (2002) and Slattery *et alia* (2011) define hierarchical response as contextual control of functional classes established via the interrelated processes of conditional discrimination and generalization. Despite the relevance of these precursor studies for RFT researchers, they do not include all the features crucial from a RFT perspective (ME, CE, and TOF). The only feature included is transitive class containment, in RFT understood as a type of CE (necessary for proving that relations between stimuli have been derived and not directly trained). Therefore, these studies served to design procedures from the RFT point of view.

In the RFT studies of the Analysis line (Gil *et alia,* 2012; Gil *et alia,* 2014; Slattery & Stewart 2014; Steward *et alia,* 2017), there is theoretical agreement on the understanding of hierarchical responding as type of relational response that has its origins in multiple-exemplar-training (MET) based on non-arbitrary relations of inclusion (or containing) and belonging to (or members of). Nevertheless, the definition that authors hold of hierarchical responding, procedural differences are visible. In the case of Gil *et alia* (2012; 2014) there is no conceptual distinction between a hierarchical response with a top-down and bottom-up transformation while Slattery and Stewart (2014) and Steward *et alia* (2017), make such a distinction.

Therefore, these conceptual differences determined training of cues used in the experiments and patterns of TOF that were predicted to differ. Gil *et alia* (2012; 2014) argue that TOF has to be bidirectional (top-down and bottom-up) even if the pattern of the transformation could differ and this pattern of TOF is found. In contrast, Slattery and Stewart (2014) argue that in the member-class type of hierarchy we should only expect Top-down transformation of functions and only this pattern of TOF was found. Nevertheless, Stewart *et alia* (2017) aim to model a different type of hierarchy collection concept (part-whole) where he expects to observe both Top-down and Bottom-up TOF. Eventually non pre-dominant pattern of TOF (1 downward unidirectional, 4 bidirectional, 2 upward unidirectional, 1 no TOF and 1 with inconsistent pattern) is obtained and authors conclude that this is due to the type of hierarchy being studied "part-whole" (Stewart *et alia*, 2017). On account of this, the results are explained by a conceptual hypothesis, where due to lack of other explanation for the obtained results (procedural analysis) it is concluded by the authors that incoherent patterns of response are due to features of "part-whole" type of hierarchy.

Analyzing the procedure allows authors of this review to hypothesize different explanations of obtained results. Since Stewart *et alia* (2017) seem to assume that in order to train "part-whole" type of responding, it is enough to train cues based on proximity (juxtaposed figures). We cannot be sure what the experimental subjects are learning by answering either to parts and compounds, and whether answering to a compound of stimuli can be understood as responding to a whole. Also in the experimental design, subjects are taught to respond to compounds of stimuli that could be either close or not. Possibly, this could possibly make them derive that in some trials individual stimuli are "members" and in other "parts" just because of the proximity between stimuli. It could explain the lack of consistency in Transformation of functions (non-predominant pattern of TOF). Therefore, this procedure does not allow to isolate if the participants are responding as it is hypothesized on a conceptual level where the incoherent pattern of TOF response is due to features of "part-whole" type of responding. Also, the authors assume conceptual differences between "member-class" and "part-whole", but the procedures do not differ significantly. Therefore, it is hard to sustain such a conceptual distinction.

Regarding the Training line in Class Inclusion studies (Ming *et alia*, 2017; Zagrabska *et alia*, 2020), the definition of hierarchical responding is understood as a capacity to respond to CI tasks, where subjects need to be able to respond to one stimulus as a member of simultaneously two categories (more and less inclusive, eg., labrador as a dog and as an animal). Authors of this line of research claim that from the RFT standpoint hierarchical relations begin in simpler relations including containment (A contains B) and comparison (A is bigger than B). Therefore, the procedure in these studies includes training in containment and comparison to improve CI tasks responding. Although, the results prove the procedure to be effective to produce CI, the relevant question would be to determine whether hierarchical classification in the form of Class inclusion, based only on nonarbitrary containment and comparison, would allow for establishment of more general hierarchical responding repertoire.

In the Relational Framing studies (Mulhern *et alia*, 2017, 2018; Kirsten & Stewart, 2021) the authors hold the definition of hierarchical responding as a complex pattern of response. They maintain that this could be tracked from it's simple to complex form by assessing and training nonarbitrary containment (relations between stimuli were presented verbally and physically; e.g., "A red box is inside a blue box" so "Is the red box inside a blue box?") and arbitrary containment (stimuli were presented but relations are described verbally without a demonstration) and also arbitrary hierarchy (e.g., "Tol is a type of Klo"). TOF is being tested, although not in all the studies.

The distinction between containment and hierarchy seems to be another conceptual difference that is not clear. This distinction is similar to that described previously as a "part- whole" vs "member- class". As such, containment (physical belonging) could be compared to "part-whole" (being part of something bigger) while hierarchy (belonging based on arbitrary properties) would be compared to "member-class" (being a member-having both less inclusive and more inclusive features).

According to authors of Patterns of Relational Framing (Training line) the capacity to respond hierarchically depends on a previous establishment of nonarbitrary and arbitrary containment that would lay the foundation for more abstract patterns of responding (arbitrary hierarchy). Although it is still not clear whether the capacity to respond to containment is the only necessary to establish hierarchical responding.

When examining these procedures in more detail, the difference between arbitrary containment and arbitrary hierarchy is only in the use of words. In the arbitrary containment, relations between stimuli are verbally described ("The red circle is INSIDE the blue one") and then tested ("Is the red circle INSIDE the blue one"). Furthermore, in the arbitrary hierarchy relations between stimuli are again verbally described ("A Tol is a TYPE of animal") and then tested ("Is Tol a TYPE OF animal"). The difference between "inside" and "type of" seems to be semantic (possibly equivalent for experimental subjects) more than one that would allow subjects to train different types of repertoires.

Also, the format of responding to these questions with YES/NO is problematic since this type of training and testing could possibly make experimental subjects learn to respond to a form of the training/testing without being able to generalize this repertoire across different hierarchical responding tasks and contexts. Likewise, TOF is being tested in both directions; therefore, the question is raised about the importance of maintaining the previous conceptual distinction between "member-class" and "part-whole" where only in "part-whole" hierarchy both directions of TOF were expected.

Research on hierarchical responding from the RFT perspective is still very scarce, as there is neither a common definition nor procedure. Therefore, there is further scope for improvement in this field, to advance in both lines of research (analysis and training) since the advancement in one can point to a research area in the other one.

The analysis line of research has advanced on the study of the use of arbitrary stimuli as hierarchical relational cues and to train the networks using these cues and to test transformation of functions. Correspondingly, the analysis line of research provided sufficient knowledge to design efficient RFT-based training protocols to assess and improve this repertoire in typically and non-typically developing children and adults (Training line). Training line of research further developed the protocols used in Analysis line, advancing on understanding of nonarbitrary and arbitrary training of relational cues and the role of different reinforcement schedules to produce hierarchical responding in typical and non- typical experimental subjects.

Despite all the advancement, hierarchical responding is difficult to define and train. It seems to be requiring training in other less complex relational frames like coordination, distinction, opposition, comparison. More studies are required that analyze the conditions in which such a repertoire is appearing, especially in subjects that don't have such repertoire. The argument by Luciano *et alia* (2009) is still very relevant, since she argued the necessity to study not just different relational frames but also studying more complex models of derived relational responding combining different frames in a much more complex way, for example: frames of coordination, opposition and hierarchical altogether. Also, distinguishing between conceptual and procedural issues while trying to answer the questions related to possible types of hierarchical responding, implications of different relational frames and generalization of this repertoire is crucial for further development of this area. Reviews such as this one, allow for the dissemination of knowledge about hierarchical responding from RFT point of view to the larger community of researchers and practitioners to advance its understanding and to offer efficient training protocols to facilitate learning of this repertoire in typical and non-typical subjects.

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