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Complexity in Concept Formation

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Abstract

Researches in behavior analysis have studied concept formation and symbolic behavior, especially within stimulus equivalence. This research area has shown that novel responding of untrained relations can emerge, following conditional discrimination training. Also, research has revealed that the order and arrangement of stimuli in conditional discrimination training, referred to as training structure, affects the formation of equivalence classes. Most research concerning effects of training structures on equivalence formation has mainly focused on the comparison of many to one (MTO), one to many (OTM), and linear series (LS) training structures. A number of articles have been published and several hypotheses have been put forward concerning this phenomenon, which will be elaborated and discussed in Article 1. This article will lay a historical, theoretical, and empirical ground for the research question in Article 2. The experiment in Article 2, one training structure combining elements of OTM and MTO are compared with LS training structure. 12 participants were trained and tested in these two conditions, and their results were compared with regards to equivalence class formation and reaction time. Incorporating an aspect of complexity in class formation, by means of integrating elements of several training structures in conditional discriminations training, might increase our understanding of concept formation and may be a reasonable scientific direction forward.

Key words: training structure, many to one, one to many, linear series, stimulus equivalence, simple discriminations account, big bag theory, number of nodes, directionality of training

On the Role of Training Structure in Stimulus Equivalence Class Formation

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Abstract

The arrangement and order of stimuli in a conditional discrimination procedure have shown to have an effect on the formation of equivalence classes. This has been referred to as training structures. The most frequently used training structures are called many-to-one (MTO), one-to-many (OTM), and linear series (LS). Research investigating the effects of training structure on emergent responding has reported MTO to yield the best results in some experiments, and OTM in others. The LS training structure has been shown to be the least effective structure in equivalence class formation. Different researchers have hypothesized as to the nature of why, and how these training structures yields differential results when participants are tested for derived relations. The present paper aims to elaborate and discuss these hypotheses in light of each other and existing evidence. One theory sets forth a proposal which emphasize that the effect of different training structures comes in contact with the participant's behavior when exposed to the test for emergent relations. That successively discriminated stimuli that were previously simultaneously discriminated and vice versa affects emergent responding. The second hypothesis argues that the number of simple discriminations presented in training affects derived relations, and the third account stresses that emergent relations are inversely related to the number of nodes in a training structure.

Key Words: training structure, many to one, one to many, linear series, stimulus equivalence, simple discriminations account, nodality, big bag theory

On the Role of Training Structure in Stimulus Equivalence Class Formation

For centuries, research on language and concept formation has been of interest in psychology and other sciences, and have been claimed to be one of the defining characteristics that distinguish humans and non-human animals. Such complex human behaviors have historically been studied structurally, but the field of behavior analysis has shown that complex behavior can be studied within the operant framework. Stimulus equivalence as a research area has shown that language and concept formation, or associative concept learning, can be studied both functionally and experimentally (Zentall, Galizio, & Critchfield, 2002).

The term stimulus equivalence was introduced by Murray Sidman in the beginning of the nineteen seventies, describing emergent responding of untrained relations. With prior experience from studying language comprehension and word relatedness in aphasic patients by using a matching to samples procedure, Sidman published his first article on stimulus equivalence and emergent responding in 1971 (Sidman, 1994). Ever since, research on stimulus equivalence, uncovering complex human behavior, has flourished as a field, identifying variables affecting equivalence class formation.

The order and arrangement of stimuli in conditional discrimination training has been referred to as training structure (e.g., R. R. Saunders & Green, 1999). In 1986, Spradlin and Saunders studied the formation of equivalence classes in developmentally disabled adolescents. They introduced stimuli in two different training structures in a conditional discrimination training procedure, and tested for emergent class-consistent responding. They found that one training structure, multiple-sample and single-comparison, increased probability of emergent responding, compared to single-sample and multiple-comparisons structure. These results were not predicted by any of the interpretations of stimulus class phenomena at that time, and introduced an unexplored research area with regards to concept formation (Spradlin & Saunders, 1986).

Interestingly, in experiments studying the effect of training structures, all baseline conditional discriminations are established to a certain criteria, usually to 90% experimenter-defined correct responding. Regardless, the probability of forming stimulus equivalence classes or symbolic behavior seems to be dependent on how the stimuli are arranged in training. Why training structures show behavioral differences in test outcome has been debated by researchers. Different theories and hypothesis have been proposed about this phenomenon ranging from simple versus successive discriminations, the number of possible simple discriminations presented in training, and the number of nodes. There are similarities between these hypotheses, but also fundamental differences, which may indicate an incomplete understanding as to how training structures affects complex human behavior and concept formation.

To get a fuller understanding of how conditional relations are trained and formed and in what way this influences the forming of concepts and verbal behavior, might have a great applicable value. The present paper seeks to question and elaborate on how the effect of training structures on stimulus equivalence class formation is described in the behavior analytic literature, and discuss if and how empirical evidence supports these hypotheses. This will be done by first defining the phenomenon of stimulus equivalence and different training structures. Further, different research results, and the challenges that exist in terms of comparing these results, will be discussed. Three approaches and hypotheses will be highlighted; Sidman's Big Bag theory (Sidman, 1994), Saunders and Green's simple discrimination analysis (R. R. Saunders & Green, 1999), and the nodal distance account proposed by Fields and his colleagues (Fields, Verhave, & Fath, 1984). The focus, throughout current paper, will be on how training structure affects responding to properties of stimulus equivalence. Other supplementary measures as, for example, number of training trials or reaction time data (Dymond & Rehfeldt, 2001) will not be elaborated.

Definitions and research

Defining Stimulus Equivalence

Stimulus equivalence is when three or more stimuli in one class are mutually interchangeable, and stimulus equivalence classes are said to have been formed when participants relationally responds to three properties; reflexivity, symmetry and transitivity (Sidman, 1992). The interchangeability is tested after conditional discrimination training. In a conditional discrimination training procedure, possibly establishing three 3-member stimulus classes, participants are presented with a sample stimulus and are asked to match this stimulus with one of three comparison stimuli, without any physical resemblance between the stimuli. Participants are taught to respond to a four term contingency through differential reinforcement. For example, when presented with a sample stimulus, A1, participants have to match this with one of three comparisons stimuli; B1, B2, or B3. Also, when presented with B1, participants have to match this with one correct out of three comparisons stimuli; C1, C2, and C3. The numbers indicate stimulus classes and the letters indicate class membership. After training participants has learned to match A1B1, B1C1, A2B2, B2C2, A3B3, and B3C3, often with accuracy over 90 percent, before testing whether stimuli are established as an equivalence stimulus class. Arntzen (2012) argues that the mastery criteria should be 95% or higher, especially, when using only two comparison stimuli, to makes sure all baseline relations are established.

The three properties that define stimulus equivalence; reflexivity, symmetry, and transitivity, are derived from the mathematical definition of equivalence (Sidman & Tailby, 1982). Conditional relations are reflexive when participants' performance shows that each stimulus is related to itself: if A, then A, if B, then B, or if C, then C. A symmetrical relation is a bidirectional relationship between the sample stimulus and the comparison stimulus and the behavioral property of symmetry is observed when participants responds; if A is B, then B is A, and if B is C, then C is B. The property of transitivity is shown when two stimuli are indirectly related because of a direct relation to a common stimulus. That is, if A is B, and B is C, then A is C. Also, a combination of symmetry and transitivity are usually tested for and observed when participants relate; if A is B, and B is C, then C is A. This has sometimes been referred to as global equivalence (Sidman, 1992). Only when these relations have been demonstrated an equivalence stimulus class is said to exist, and one can say that the participants' performance is in accordance with stimulus equivalence (Sidman & Tailby, 1982).

Three Training Structures

Training structure refers to the order and arrangement of stimuli in training, and there are mainly three training structures that have been used in stimulus equivalence research; many-to-one (MTO), one-to-many (OTM), and linear series (LS) (R. R. Saunders & Green, 1999). When trained in MTO participants learn to match stimulus A to stimulus C and stimulus B to stimulus C. In this structure, two or more stimuli function as sample stimuli in the conditional discrimination training procedure, A and B, while only one stimulus function as comparisons stimuli, stimulus C. The use of stimuli as sample or as comparison in training is referred to as directionality of training (Fields & Verhave, 1987). In OTM, the directionality of training is reversed. The participants learn to match A to B and A to C, resulting in one stimulus functioning as a sample stimulus and two or more stimuli as comparison stimuli. When trained in LS the directionality of training is again changed and participants are taught to match AB and BC. In this structure, the B stimulus serves a dual function in training, as both sample and comparison stimuli, while A and C, serve only one function; as sample and comparison, respectively. Training structures can, as mentioned, be arranged in different ways and are built up of nodes and singles. Nodes are stimuli connected to at least two stimuli by training. Single stimuli, or singles, are stimuli only connected to one other stimulus by training. For example, in LS, A and C stimuli are singles and B stimulus is a node. Training structures can vary with regards to the number of stimuli in a class, number of nodes, distribution of singles, and directionality of training (Fields & Verhave, 1987).

Differential Outcome on Test for Equivalence as a Function of Different Training Structures

During the early 1980s', scientists within the field of stimulus equivalence viewed class size and number of intervening nodes as factors affecting relational responding, and directionality of training as an indifferent factor (R. R. Saunders et al., 1988). With a purpose to replicate Spradlin and Saunders (1986) results, which showed differential outcome on emergent responding as a function of training structures, Saunders, Wachter and Spradlin (1988) studied the function of directionality of training by comparing the training structures MTO and OTMs effect on equivalence class formation. In the first phase of their experiment, six participants with developmental disabilities were trained to possibly establish two 5-member classes of abstract stimuli. All three participants trained in MTO responded in accordance with stimulus equivalence, while only one out of three did so in OTM, providing evidence that directionality of training might be an influential variable for emergent responding.

Other experiments have been conducted by different researchers over the years. An overview of experiments investigating the effects of training structure on stimulus equivalence class formation is presented in Table 1. This table displays the many variables that differ in these experiments. Experiments have varied with regards to class size, number of classes, number of comparison stimuli, abstract and familiar stimuli, participants, design, consequences for baseline trials in testing, and instruction giving to mention some. All these variations impede the possibility of comparing results and draw causal conclusions about effects of training structures. Despite these variation, there seems to be an overall tendency that MTO produce a higher outcome in test with children and people with developmental disabilities (e.g., K. J. Saunders, Saunders, Williams, & Spradlin, 1993; R. R. Saunders, Drake, & Spradlin, 1999; R. R. Saunders et al., 1988; Spradlin & Saunders, 1986), and that OTM produce a higher outcome in test with adults (e.g., Arntzen, Grondahl, & Eilifsen, 2010; Arntzen & Holth, 1997, 2000). Other experiments show little or no difference between MTO and OTM with regards to emergent responding (e.g., Arntzen & Hansen, 2011; Arntzen & Nikolaisen, 2011; Smeets & Barnes-Holmes, 2005). What appears to be evident is that LS is the training structure that have shown to be the least efficient in producing stimulus equivalence class responding, out of the three structures (e.g., Arntzen et al., 2010; Arntzen & Hansen, 2011; Arntzen & Holth, 1997, 2000; Arntzen & Nikolaisen, 2011; R. R. Saunders, Chaney, & Marquis, 2005; R. R. Saunders & McEntee, 2004).

The Conceptualization of Training Structures in Equivalence Class Formation

Sidman's Big Bag Theory

Sidman (2000) regards responding to properties defining equivalence classes as a basic behavioral phenomenon, and a direct outcome of history with reinforcement contingencies. And that training produce both analytic units, that is, 2-, 3-, 4-, or n-term contingencies, and equivalence relations, which "consist of ordered pairs of all positive elements that participate in the contingency" (p.128). Sidman uses a "bag"-analogy to describe equivalence relations; all ordered pairs of positive elements that participated in the contingencies can be tossed in a bag and are equally related to and interchangeable with each other.

Using the mathematical set theory of equivalence relations as a parsimonious descriptive system elaborating stimulus equivalence, Sidman argues that there should be no differences between different training structures in emergent responding;

> In specifying the ordered stimulus pairs that make up an equivalence relation, the mathematics takes no account of which member of pairs is listed first; the AB pair has no properties that differentiate form the BA pair in the sample relation (Sidman, 1994, p. 538)

Further, Sidman writes that if variations of the training structure show behavioral differences the mathematical model does not fully describe equivalence relations. Any behavioral differences as a function of the training structure should be attributed to well-known behavioral variables and principles of stimulus control, like simultaneous versus successive discriminations.

The Simple Discrimination Analysis

Saunders and Green (1999) offer an approach that is not far from Sidman's analysis but with some distinctively differences. Whereas Sidman's analysis emphasizes that any difference between training structures will be discernible in test for emergent responding, the simple discrimination account also focuses on differences in training as a result of the arrangement of stimuli. They write that their analysis is coherent with basic stimulus control principles and is based on the assumption that "for performance to meet criteria for acquisitions of the trained baseline relations as well as criteria for positive outcomes on all tests for stimulus equivalence, each stimulus must be discriminated from every other stimulus in the experiment" (R. R. Saunders & Green, 1999, p. 120). To conditionally discriminate, as the procedure requires, participants must discriminate each stimulus from each other and not only discriminate between classes of stimuli; they have to simultaneously discriminate between every comparison stimuli and successively discriminate between every sample stimuli. According to the account, simple discriminations are embedded in conditional discriminations, and the more simple discriminations acquired in baseline training, the higher the likelihood would be that the participants responds accurately when tested for derived relations. Training structures that enhance the probability that every stimulus gets discriminated from every other stimulus in training increases probability of establishing an equivalence class (R. R. Saunders & Green, 1999).

The simple discrimination analysis claims that the MTO training structure teaches all the simple discriminations necessary to respond to the derived relations during the conditional discrimination training while OTM and LS do not (R. R. Saunders & Green, 1999). For example, when establishing a two 3-member stimulus class with conditional discrimination training, the participants are exposed to all 15 simple discriminations necessary in MTO. When AC and BC relations are trained, participants are exposed to simple successive discrimination between all A stimuli, and all B stimuli as sample (two discriminations). Participants are also exposed to simultaneous simple discriminations between A and C stimuli, and B and C stimuli (eight simple discriminations), and exposed to successive simple discriminations between the comparison stimuli, A and B, when trials are mixed (four discriminations). When trained in OTM or LS participants are only exposed to 11 simple discriminations. In the OTM structure participants learn AB and AC relations, and the structure is arranged so that participants will not be exposed to simple discriminations between the two comparison stimuli; B and C. In LS, AB and BC relations are trained. Here, participants are not exposed to simple discriminations between A and C stimuli (R. R. Saunders & Green, 1999).

The total number of simple discriminations presented in training increases as the number of classes and number of stimuli per class increases, as do the number of simple discriminations not presented in OTM and LS. Based on this, Saunders and Green (1999) predicts that negative results will more likely follow OTM and LS than MTO, due to the difference in number of simple discriminations presented in training, and that this difference is readily seen with large classes or high number of class members. Also, because of limited exposure to possible simple discriminations in training, in OTM or LS, participants are exposed to these simple discriminations without differential reinforcement during testing, which may result in gradual emergence of equivalence class formation (R. R. Saunders & Green, 1999).

Nodal Distance

Fields and his colleagues propose an account with nodes and directionality of training as accountable variables, when explaining the differences in test performance as a function of training structures. This approach suggests that responding to transitive and global equivalence trials is inversely related to the number of nodes that separate two stimuli, and has been called nodal distance or “associative distance” (Fields, Adams, Verhave, & Newman, 1993; Fields & Verhave, 1987; Fields et al., 1984). This approach indicates that stimuli in an equivalence class are not equally related, but related differentially to each other because of the dissimilar number of nodes separating two stimuli affecting responses under transitive and equivalence control. By this notion, LS would result in lower yields when testing for emergent relations than the two other structures.

Nodes are defined as stimuli that are connected to at least two other stimuli as a result of training, and can be connected to singles or other nodes. For example, in a LS structure with five members, participants are trained to match AB, BC, CD, and DE. When later tested for derived relations of transitivity, AC, BD, and CE are called one-node (1N) trials because of the one node separating the two stimuli. AD and BE trials are called two-node (2N) trials, and AE are three-node (3N) trials because the stimuli in the relation are separated by two and three nodes, respectively (Fields & Verhave, 1987). Likewise, global equivalence trials can be identified according to the number of nodes separating the sample stimulus and the comparison stimulus, for example EA test trial is a 3N global equivalence trial.

The nodal distance account argues that stimuli in an equivalence class are substitutable with each other, but not equally related to each other. Their relatedness is seen as an inverse function of nodal distance (Fields, Adams, & Verhave, 1993; Fields & Moss, 2007), which means that 1N relations are more strongly related to each other than, for example, 2N or 3N relations, resulting in lower conditional control when nodal distance between stimuli increase.

Fields, Adams, Verhave and Newman (1990) used a conditional discrimination procedure to established two 4-member classes of nonsense syllables. All seven participants were trained in a LS manner. AB and BC relations were trained first, and then derived 1N and symmetry relations were tested before CD relations were trained. Lastly, derived relations were tested again. Results from this study show that on average 1N trials exerted more conditional control than 2N trials. According to the authors this verifies an inverse function of nodal distance on accuracy in emergent responding. In 1993, the same authors found that stimuli in a formed two 5-member equivalence class of nonsense syllables trained in a LS manner, were related differently in a transfer test as an inverse function of nodal distance. After establishing AB, BC, CD, and DE relations, they taught stimuli A1 and A2 to occasion a motor response, and measured how this response would transfer to other member of the same class under an extinction procedure. The results they found confirmed that stimuli in an equivalence class were related as an inverse function of nodal distance separating two stimuli. Other studies have shown similar results (e.g., Bentall, Jones, & Dickins, 1998; Fields, Landon-Jimenez, Buffington, & Adams, 1995; Kennedy, 1991; R. R. Saunders et al., 1988).

The Effect of Training Structures on Emergent Responding; Hypotheses, Empiricism and Criticism

According to the definition of stimulus equivalence, stimuli in a class are interchangeable with each other, regardless of directionality of training or number of intervening nodes separating two stimuli due to structural procedure in conditional discrimination training (Sidman & Tailby, 1982). Existing empirical evidence both affirm and refute different accounts contemplating or explaining the effect different training structures have on stimulus equivalence class formation.

As described earlier, Saunders and Green (1999) proposes some testable hypothesis as steps in the direction towards confirming the simple discrimination approach with regards to the effects training structures have on equivalence class formation. The main hypothesis is that positive results are more likely to follow MTO, than OTM and LS, due to a higher number of simple discriminations presented in the former than the two latter. Also, this effect will be more prevalent in larger classes or higher number of classes trained and tested, since there are less discrimination demands when classes are smaller and there are fewer classes, and other types of simple discriminations components required (R. R. Saunders & Green, 1999). The simple discrimination account does not discuss explicitly the size of predicted discrepancy between the outcome of OTM and LS, but argue that in OTM, and not LS, participants are exposed to simple discriminations in test that were not presented in training.

As Saunders and Green (1999) points to in their article, some experiments are consistent with their analyses whereas others are inconsistent; "Although our review suggests that published research on stimulus equivalence provides some support for the discrimination analysis of training-structure effects, the evidence in neither overwhelmingly confirmatory nor disconfirmatory" (p. 133). Evidence from contemporary research comparing MTO and OTM, other than those discusses in Saunders and Green's article, has also shown divergent results. Some studies have shown a higher positive outcome in test for stimulus equivalence relations after MTO (Hove, 2003; R. R. Saunders et al., 2005; R. R. Saunders & McEntee, 2004), some have shown that OTM produced higher yields in test (Arntzen & Holth, 1997, 2000), and other studies have shown no or very little difference between MTO and OTM (Arntzen et al., 2010; Arntzen & Hansen, 2011; Arntzen & Nikolaisen, 2011; Arntzen & Vaidya, 2008). Those studies that include LS, have found that LS has the lowest outcome of all structures in establishing equivalence classes (Arntzen et al., 2010; Arntzen & Hansen, 2011; Arntzen & Holth, 2000).

Arntzen and Holth (2000) question Saunders and Green (1999), with regards to their analysis, that the MTO training structure presents or require more simple discriminations than OTM. “[…] in the MTO training structure nothing seems to enforce discrimination between A1, C1, and D1 (presented as samples) when touching B1 (presented as comparison)” (pp.625–626). Saunders and Green write that when training trials are mixed, within-class sample stimuli are successively discriminated. Further, Arntzen and Holth (2000) argues that experiments using two-choice compared to three-choice matching task, have shown a MTO superiority in equivalence class formation relative to OTM. Two choice matching has been argued to possibly induce rejection control, and that this may be a critical variable for incorrect outcome on equivalence tests (Carrigan & Sidman, 1992; Sidman, 1987). Arntzen and Holths (2000) Experiment 2 compared two- and three- choice matching tasks in both MTO and OTM, and found no differences with regards to training structures and number of comparisons stimuli. Saunders, Chaney, and Marquis (2005), increased classes and class size and found opposite results of those of Arntzen and Holth (2000), where MTO produced higher equivalence class consistent responding than OTM, supporting Saunders and Greens hypothesis.

Sidman (1994) argues that any difference between MTO and OTM does not make contact with the participant in the training, but in the test, testing properties of transitivity or global equivalence. Whereas, Saunders and Green (1999) would argue that differences in the arrangements does make contact with the participant in training, due to the number of simple discriminations the participants are exposed to. Sidman write that it is after the conditional discriminations have been established participants have to “switch” between simultaneous and successive discrimination. For example with MTO, participants have to simultaneously discriminate between A- and B- stimuli, which previously functioned as a sample and were successively discriminated by the participant. Baseline relations established in OTM arrangement entails that a participant has to simultaneously discriminate between sample stimuli in the test, which has previously functioned only as comparison stimuli. Further, Sidman emphasizes that the effect of going from simultaneous to successive discrimination from training to test or vice-versa might be of more relevance than attributing the differences between structures to directionality of training (Sidman, 1994).

Evidence does somewhat confirm the simple discrimination account; that LS results in lower yields with regards to equivalence class formation, then MTO. There seems to be little or no difference between OTM and MTO. As Saunders and Green (1999) points out, this may reflect the validity of their analyses or the complexity in this type of research.

Sidman (1994) argues that terms like nodal distance and directionality stems from the view that there is a linear association regarding stimulus control and that such a description might not be suitable for the phenomenon stimulus equivalence, nor characterize stimulus control in general. The nodal distance approach has been criticized conceptually, with regards to the concept of nodal distance, and methodologically, concerning that there may be other variables that are responsible for the differences found with respect to nodal distance, than those described in some of the literature, hence, questioning the number of nodes as the primary cause (Imam, 2001; Sidman, 1994). Using a structural label, as nodal distance, might lead to the implication of a hypothetical structure at work, and should therefore be avoided according to Sidman (1994). Also, Saunders and Green (1999) argues that the nodal distance perspective "… falls short of explaining different outcomes on tests for equivalence in basic behavioral terms" (p. 119). The nodal association account differs from the two other approaches with respect to the concept of stimulus classes and its definition of interchangeability and mutual relatedness among stimuli in a class (Imam, 2006; Tomanari, Sidman, Rubio, & Dube, 2006).

Conditional discriminations are usually presented in a serialized manner in training, by establishing one relation at the time with mixed phases in between, leaving some relations to be presented more often than others (Arntzen, 2012). One example of serialized presentation of trials is as follows: first AB relations are trained, then BC relations. Then AB and BC relations are mixed, followed by training of CD relations. Further AB, BC, and CD relations are mixed and so on, depending on class size. Empirical evidence underpinning effects of nodal distance on emergent responding often presents conditional discriminations in a serialized manner. Unequal numbers of reinforcement contingencies presented in training is one procedural variation that has been suggested as a confounding variable when effects of nodal distance have been reported. Imam (2001, 2006) raises this issue and argues that due to the nature of a LS training structure, fewer reinforcement contingencies are provided for relations that are presented later in training. Results from these studies show that by equalizing the number of training trials, and thus, the number of reinforcement contingencies, the effect of nodal distance diminishes with regards to accuracy and speed (Imam, 2001, 2006). Also, across different training protocols (Imam, 2006). Fields and his colleagues have criticized Imams research for being designed in a non-neutral way to eliminate any effect of nodal distance (Fields & Moss, 2007).

Wang, Dack, McHugh and Whelan (2011) tested this notion of unequal presentation of reinforcement contingencies in training as a confounding factor when reporting nodal distance effects. Here, participants were trained under different conditions; one, where trials were presented concurrently (equal reinforcement contingencies, Experiment 1, 2, and 3) and one, where trials were presented in a serialized manner (unequal number of reinforcement contingencies, Experiment 1 and 2). Results, with regards to accuracy of emergent relations, were that all three experiments showed a small nodal distance effect despite equalizing trials presented of each relations, though none were statistically significant (Wang et al., 2011). The later study differs from those of Imam in several ways, but the main difference was that they only used two comparison stimuli, instead of three.

A majority of the studies reporting of nodal distance effects in emergent responding establish two equivalence classes and, therefore, only use two comparison stimuli during training and testing (Fields, Adams, & Verhave, 1993; Fields et al., 1990; Fields et al., 1995; Fields et al., 1997; Fields & Watanabe-Rose, 2008; Moss-Lourenco & Fields, 2011). Sidman and others have argued that when using only two comparison stimuli when establishing conditional discriminations, there is a greater probability that the participants performance is under rejection control and not the contingencies intended by the experimenter (Carrigan & Sidman, 1992; Sidman, 1987, 1994). This might be a confounding variable with regards to reported nodal distance effects, since responding may be under control of the negative comparison and not under control of the class consistent comparison stimulus. Kennedy (1991) examined the effect of the numbers of nodes on equivalence class formation, and found that when increasing from two to three comparison, or establishing two versus three equivalence classes, with 7 members, the effect of nodal distance decreased. In Kennedy's experiment, the training structure differed from a traditional LS training structure in terms of directionality of training, where participants were taught AB, AC, BD, BE, CF, and, CG, creating a 7 member three node class. Also, the conditional discrimination training was conducted manually as a table top procedure, and not automatically on a computer. Boelens

(2002) questions Sidman's skepticism to a two choice procedure, and argues that potential rejection control can be avoided raising accuracy criteria to 100%.

Some researchers have taken Sidman's consideration about rejection control into account when examining effects of nodal distance, establishing only two stimulus classes by adding a null stimulus, or a "dummy" that is not from another stimulus class (Moss-Lourenco & Fields, 2011). Questions could be raised whether such a procedure avoids rejection control. The null stimulus is never a part of a four-term contingency, and with repeated training where the null stimulus is always "left out", it might decreasing attending to that stimulus and enable rejection control between the two other stimuli. Sidman (1994) writes that all stimuli in a test, both positive and negative, should be given equal reinforcement history.

Delayed Emergence and LS: Two Perspective

Both the simple discriminations and the nodal distance account have discusses some behavioral predictions in regards to emergent responding following LS, referred to as gradual emergence. Sometimes, emergent relations are not observed immediately on the first test after the conditional discrimination training procedure, this has been referred to as delayed emergence. Repeated testing have shown gradual class emergence. Fields and Moss (2007) write that reinforcement contingencies establishing conditional discriminations in a LS training structure have three effects; impose a nodal structure on the stimuli within a class establishing differential relational strength, establishing relations among the stimuli classes, and establishing discriminations between stimuli in different classes. Performance occasioned by test trials can be influenced by these factors. When immediate emergence is observed after conditional discrimination training with LS, this suggests that the procedure "maximized the control between-class discriminations and maximally suppressed the expression of nodal distance" (Fields & Moss, 2007, p. 153). Whereas, when delayed emergence is observed, control by between-class discriminations are not maximized, and effect of nodal distance is expressed. Confirmation of nodality effect would be observed if 1N relations emerged prior to 2N relations, and 2N relations emerge prior to 3N relations and so on.

Saunders and Greens (1999) also hypothesis about delayed emergence of equivalence class responding during testing when trained in LS. According to the simple discriminations account, derived relations would emerge differently than proposed by Fields and his colleagues (e.g., Fields et al., 1984). Patterns of responding that have been attributed to nodal distance, according to the simple discriminations account, may be due to gradual acquisition of the simple discriminations necessary as a function of stimulus presentation frequency. When training three five-member equivalence classes in a LS fashion (AB, BC, CD, DE), three are 105 simple discriminations in total to be made, and 54 of these are not presented in training, but called for on test trials. When presenting all test trials interspersed with baseline trials, trials involving B, C, and D stimuli will be presented more often that A and E stimuli. "If previously untrained discriminations develop over the course of testing… then we hypothesize that the order in which those untrained discriminations are acquired will correspond to the frequency of reexposure to particular stimuli on baseline trials during testing" (R. R. Saunders & Green, 1999, p. 130). According to this BD and DB test trials will produce positive results first, then AC, CA, CE, EC, AD, DA, BE, and EB trials, and lastly AE and EA test trials.

In 2012, Wang, McHugh, and Whelan, examined the simple discrimination and the nodal distance account hypotheses, and their predictions with regards to delayed emergence of derived relations following conditional discriminations trained in a LS training structure. In this experiment, 40 college students were exposed to a conditional discriminations training procedure, where two 5-member classes of pseudo word stimuli were established. Trials were presented concurrently, and when performance reached 100% correct criteria feedback gradually faded before exposed to a test phase. The test consisted of baseline, symmetry, transitive and equivalence relations randomly, where each relation was only presented once in a block. Test block repeated until mastery criteria of 85% were reached. With regards to response accuracy on test performance, the results show a slight favor to the nodal distance account; 29% of the participants showed sole consistency with the nodal distance account, while 24 % showed that to the simple discrimination account. Moreover, 33% of the participants showed features of both, whereas, 14% demonstrated features of neither account. When test cycles were averaged across participants, 30% of the cycles favored the nodal distance account and 20% favored the simple discrimination account. In this study two equivalence classes were formed and in the procedure only two comparison stimuli were presented in each trial. Two-choice matching has, as mentioned, been discussed as a confounding variable with regards to nodal distance effects and might facilitate rejection control (Imam, 2006; Sidman, 1994). Also, using pseudo words as stimuli might make it difficult to compare these results to other studies that have used abstract stimuli.

Three 3-member Classes

Some studies have compared all three training structures by establishing three 3-member classes (Arntzen et al., 2010; Arntzen & Hansen, 2011; Arntzen & Holth, 1997, 2000). Interestingly, results from these studies seem to contradict or question the validity to both Saunders and Greens simple discrimination analysis and the nodal distance account. First, both Arntzen and Holth (1998, 2000) experiments found that participants trained in OTM had the highest yields in tests for equivalence relations, whereas, the two other studies, by Arntzen et al. (2010) and Arntzen and Hansen (2011), results showed small differences between MTO and OTM in emergent responding. These results are opposite Saunders and Greens predictions, as well as Sidman’s argument for simple versus successive discriminations. Secondly, in all those four experiments the LS training structure yielded the lowest outcome. This might support Saunders and Greens prediction, but these results can hardly be attributed to the nodal distance account (Fields et al., 1984), since the number of nodes are the same for all structures, or to nodal numbers (Sidman, 1994), or to a history with number of contingencies required to respond correctly (Imam, 2006). All three structures have one node and two singles in three 3-member stimulus classes. Saunders and Green (1999) argues that difference between training structures are more readily seen when the number of classes increase and classes are larger, and this might be a reasonable argument related to the absent difference between MTO and OTM. There seems to be something in the nature of LS affecting behavioral properties that is not due to nodes nor, maybe, simple discriminations.

Stimulus Function

The analytic unit of behavior in matching-to-sample performance has been argued to be more parsimonious and best interpreted as a four-term contingency (Jones, 2003; Jones & Elliffe, 2013; Sidman, 1994). In a four-term contingency a comparison stimulus functions as a discriminative stimulus, signalizing reinforcement of a certain response, and a sample stimulus functions as a conditional stimulus, determining the discriminative function to the comparison stimuli. In MTO and OTM, each stimulus serves only one of these functions in training, either as a conditional stimulus or a discriminative stimulus. In a LS training structure some stimulus serve two functions when establishing conditional discriminations. For example, in a stimulus class with three members (A, B, and C), the A stimulus serves only as a conditional stimulus, the B stimulus serves both as a conditional and a discriminative stimulus, and the C stimulus functions only as a discriminative stimulus.

When relations are trained in the three structures, participants' performances have to reach a certain criteria of accuracy set by the experimenter. This may imply that any effect of some stimuli serving duals functions might not influence the establishing phase of the conditional discriminations in training. But, it may play a part in maintaining conditional control in test and when responding to emergent relations. How or if this affects equivalence class formation is yet to be elaborated on, but there may seem to be a functional difference between the three training structures, also, when the stimulus classes are small.

Conclusion

The present article has elaborated on three hypotheses that are most prevalent in the stimulus equivalence literature with regards to training structures and emergent responding; Big Bag Theory, simple discrimination account, and nodal distance account. These three accounts have been discussed and criticized in light of empirical evidence and other scientists' evaluations. Also, the challenges that exist in comparing results from experiments researching effects of training structure have been emphasized. Results from a number of experiments show that there seems to be differential outcome on emergent responding as a function of different trainings structures. Notwithstanding all the different variations in these experiments, the tendency seems to be that when trained in a LS training structure the probability of responding in accordance to properties defining stimulus equivalence are reduced compared to when participants are trained in OTM or MTO. Also, studies that show difference between OTM and MTO, appears to depend on the participants involved in the study.

To identify the role number of simultaneous and successive discriminations have in regards to equivalence class formation, experiments have to be carefully designed. Sidman (2011) write that this can be done by designing experiments where the relative number of times each stimulus is involved with simultaneous and successive discriminations varies, while holding training structures constant. Arntzen (2012) emphasize this as an important direction in further research, alongside effects of stimuli functioning both as sample and comparisons. Perhaps, by going into a detailed analysis of the effects different properties of trainings structure have on emergent responding, some of these questions might be answered.

On the one hand, studying effects of training structure in stimulus equivalence class formation might be portrayed as molecular and narrow, and the immediate applicable value may be obscure. But on the other hand, “what looks like a limited problem caused by differences in experimental structures is actually a more general problem about what goes on during learning” (Sidman, 2011, p. 369). Identifying these variables and their effect with regards to concept formation and symbolic behavior might be of great applied significance, for example, in teaching, and is important for an overall understanding of human behavior.

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Table 1

Overview of Experiments Investigating Effects of Training Structure

Authors, Year	Training Structures	Most Efficient Structure	Least Efficient Structure	Design	Participants (years)	# of Choices in MTS task	Stimuli Classes	Stimuli Members	Types of Stimuli	Instruction Given
Spradlin & Saunders, 1986	MTO/OTM	MTO	OTM	WSD	Dd Adolecsent	2	2	5	Abstract	Yes
Saunders, Wachter, & Spradlin, 1988	MTO/OTM	MTO	OTM	WSD	Dd Adolecsent & Adults	2	2	8	Abstract	Yes
Saunders, Saunders, Willams, & Spradlin, 1993	MTO/OTM	MTO	OTM	WSD	Dd Adolecsent & Adults	2	6	4	Abstract	Yes/No
Arntzen & Holth, 1997	MTO/OTM/LS	OTM	LS	Group	Adults	3	3	3	Abstract	No
Fields, Hobbie-Reeve, Adams, & Reeve, 1999	MTO/OTM	MTO	OTM	Group	Adults	2	2	5+7	Nonsense Syllables	No
Saunders, Drake, & Spradlin, 1999	MTO/OTM	MTO	OTM	Group	Children (3-5)	2	2	5	Abstract	Yes
Arntzen & Holth, 2000	MTO/OTM/LS	OTM	LS	WSD	Adults	3	3	2+3	Abstract	No
Hove, 2003*	MTO/OTM	MTO	OTM	Group	Adults	3	3	3	Abstract	No
Saunders, Chaney, & Marquis, 2005	MTO/OTM/LS	MTO	LS	WSD	Seniors	2+3+4	2+3+4	3+4	Abstract	Yes
Smeets & Barnes-Holmes, 2005	MTO/OTM	No Difference		Group	Children (5-6)	2	2	5	Abstact/ Familiar	Yes
Arntzen & Vaidya, 2008	MTO/OTM	MTO	OTM	WSD	Children (7-13)	2+3	2+3	3+4	Abstract	No
Arntzen, Grondahl, & Eilifsen, 2010	MTO/OTM/LS	OTM	LS	WSD	Adults & Children (10-13)	3	3	3	Abstract	No
Arntzen & Hansen, 2011	MTO/OTM/LS	OTM	LS	Group	Adults	3	3	3+6	Abstract	No
Arntzen & Nikolaisen,, 2011	MTO/OTM	OTM	MTO	Group	Children (8-9)	2	2	5	Abstact/ Familiar	No

Note. MTO = many to one, OTM = one to many, LS = linear series, WSD = within subject design.
*In Hove (2003), errorless training procedure was used, and incorrect baseline trials in test were followed by a consequence of 5-s blank screen and repetition of the last trial, arranged in a VR3 schedule.

Stimulus Equivalence and Effects of Directionality of Training

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Abstract

Class size, number of nodes, the distribution of singles, and directionality of training are variables in relation to a training structure that can affect the establishment of an equivalence class. Research within the field of stimulus equivalence has shown that class size, number of nodes and different training structures in conditional discrimination procedure affects the outcome when testing emergent relations. How and if different directionality affects emergent responding has not yet been explored. The purpose of the present study was to examine how directionality of training affects emergent responding, effect of number of nodes, and reaction time, by arranging two training structures varying in unidirectionality while holding class size, number of nodes and distribution of singles constant. 12 participants were exposed to two conditional discrimination procedures to possibly forming three 5-member classes of arbitrary stimuli in both conditions, and were tested for emergent relations. The experiment was conducted as a mixed within subject and between group design. Results show differential outcome on symmetry and previously trained trials in test between the two conditions, and an effect of order. Results from reaction time data show an increase from previously trained trials in test to symmetry trials and a further increase on equivalence trials.

Key words: directionality of training, training structure, number of nodes, stimulus equivalence

Stimulus Equivalence and Effects of Directionality of Training

In behavior analysis, conceptualization or categorization is when an individual responds differently to classes of stimuli with no identical features. This has been referred to as concepts or symbolic meaning (Zentall, Galizio, & Critchfield, 2002). The phenomena of stimulus equivalence have shown to be a prominent research area when studying human behavior such as concept and language formation, and problem solving. Research shows that when arranging reinforcing contingencies for some stimulus-stimulus relations, participants are able to respond to relations that have never been directly reinforced. This behavioral phenomenon is not as prevalent in nonhuman animals, which makes stimulus equivalence an interesting area within behavior analysis, alongside verbal behavior.

Stimulus equivalence is defined by the mutual interchangeability of three or more stimuli in a class, and when relational responding to three properties; reflexivity, symmetry and transitivity, emerge (Sidman, 1992). Responding to these properties is referred to as novel responding to emergent relations. Stimuli in an equivalence class control the same response as a result of a history with conditional discrimination training (Green & Saunders, 1998).

In a standard conditional discrimination training procedure, participants are shown one sample stimulus together with multiple comparison stimuli, and are asked to match the correct comparison stimulus to the present sample stimulus. Selection of a correct comparison stimulus is followed by a positive consequence, for example the word “correct”, and selection of an incorrect comparison stimulus is followed by a negative consequence, for example the word “incorrect”. An incorrect comparison stimulus in one trial functions as a correct comparison stimulus in the presence of another sample stimulus. Here, participants have to discriminate successively between sample stimuli and simultaneously between comparison stimuli. Conditional discrimination performance has been established due to four-term contingencies set up by the experimenter. Four-term contingencies are three-term contingency is under the control of a conditional stimulus that guides responding (Sidman, 1986). In a conditional discrimination training procedure, the sample stimulus functions as a conditional stimulus and the comparison stimulus functions as a discriminative stimulus (Sidman, 1992). These types of matching trials or conditional discriminations are presented repeatedly until the participant's performance has reached a mastery criteria set by the experimenter, before participants are tested for emergent relations.

In the conditional discrimination training procedure, participants have learned to match stimulus A with B, and stimulus B with C, possibly establishing a three member stimulus class. After which, participants are tested for properties of stimulus equivalence. Reflexivity is seen when the participant identifies a stimulus with itself; if A, then A, if B, then B, or if C, then C. Reflexivity is a form of generalized identity matching (Sidman, 1992). Symmetrical relations are observed when participants respond to a bidirectional relation between a sample and a comparison stimulus: if A is B, then B is A, or if B is C, then C is B. Transitivity is observed when the participant relates two stimuli with a common stimulus, if A is B and B is C, then A is C. Also, a combination of symmetrical and transitive relations are tested and observed when participants relate the C stimulus to the A stimulus. This is sometimes referred to as global equivalence (Green & Saunders, 1998). When testing for emergent relations with adult participants, one usually does not include the test for reflexivity due to a possible disruption of emergent responding (Sidman, 1994). When the participant is responding to all of these untrained relations an equivalence stimulus class has been formed, and the participant is said to respond in accordance with stimulus equivalence.

Researchers have investigated how different manipulations of the training procedure affects conditional discrimination control, and responding in accordance with stimulus equivalence (for an overview see, Arntzen, 2012). The effect of different training structures and directionality of training on emergent responding has been a variable of interest. The order and arrangement of the stimuli in conditional discrimination is called training structure (R. R. Saunders & Green, 1999). There are three main types of training structures that have been used in stimulus equivalence research. One is called one-to-many (OTM) and in this training structure participants learn to match stimulus A to B, and stimulus A to C. This type of structure has also been referred to as sample-as-node. A node is a stimulus that is linked to at least two other stimuli by training (Fields & Verhave, 1987), and in OTM training structure the A stimulus is a node. The B and C stimuli in this arrangement are called single stimuli or singles. Singles refers to stimuli that are only linked to one other stimulus as a result of the training. Another training structure is many-to-one (MTO), also called comparison-as-node, where the participant learns to match A to C, and B to C. In MTO, the C stimulus is a node, while, A and B stimuli are singles. Linear series (LS) is the third training structure, where participants learn to match A to B, and B to C. In this arrangement, the B stimulus is a node and the A and C stimuli are singles. It is only after participants have been trained with a LS training structure that it is possible to differentiate between transitivity (AC relation) and global equivalence relations (CA relation). In OTM and MTO these relations are not independent, and one cannot identify transitive relations without a symmetrical aspect. When analyzing test results, these relations are referred to as equivalence relations.

Several studies have shown that outcome on test for equivalence properties varies as a function of different training structures. Some studies show that training conditional discriminations with MTO results in higher outcome in test for equivalence (Fields, Hobbie-Reeve, Adams, & Reeve, 1999; K. J. Saunders, Saunders, Williams, & Spradlin, 1993; R. R. Saunders, Chaney, & Marquis, 2005; R. R. Saunders, Drake, & Spradlin, 1999), whereas other studies have shown that OTM is more efficient in producing matching to sample performance (Arntzen & Holth, 1997, 2000a). Other studies show small difference between MTO and OTM with regards to outcome on test for equivalence properties (Arntzen, Grondahl, & Eilifsen, 2010; Arntzen & Hansen, 2011; Arntzen & Nikolaisen, 2011). Results from studies comparing these three trainings structures, show that LS is the least efficient training structure to produce equivalence classes (e.g., Arntzen et al., 2010; Arntzen & Holth, 1997, 2000a; R. R. Saunders & McEntee, 2004).

Fields and Verhave (1987) propose four parameters that describe the structure of stimulus equivalence classes. These parameters can be varied with regards to the organization of stimuli in a class, and are according to the authors, prone to have a behavioral effect on derived responding. The four discussed parameters are: class size, distribution of singles, number of nodes, and directionality of training. These four parameters can be regarded as somewhat independent from each other but they also co-vary. For example, increasing class size may increase the number of nodes depending on directionality of training.

Class size refers to the number of stimuli in a class. Increasing class size increases the number of derived relations exponentially. Increasing number of stimuli in a class affects OTM and MTO training structures differently than the LS training structure. In LS, the numbers of nodes increase as a function of increased class size, whereas the number of singles remains the same. In OTM and MTO the number of nodes will always be one while the number of singles increases along with increased class size. Research has shown that responding in accordance with stimulus equivalence is lower as a result of increased class size compared to an increase in number of classes for both LS and MTO, but lower yields in LS than MTO (Arntzen & Holth, 2000b). Distribution of singles refers to the number of singles related to a node and has been termed ‘nodal density’, and “manipulations of the distribution of singles produces a vast number of unique conditions for establishing equivalence classes, each resulting in different nodal densities” (Fields & Verhave, 1987, p. 322). Increasing class size in MTO or OTM, training structures increases nodal density.

Nodes are stimuli linked by training to at least two other stimuli, and training structures varies with regards to the number of nodes. In a five member equivalence class, with stimuli A, B, C, D, and E, trained in a LS training structure, transitive relations can be 1-node (AC, BD, or CE), 2-node (AD or BE) or 3-node relations (A-E). Fields and Verhave (1987) write that the number of intervening nodes that separate the stimuli in transitive or global equivalence relations can be called "associative distance". The author's propose that responding to transitive and global equivalence relations are inversely related to the number of nodes, that is; accuracy on derived relations decreases as the number of intervening nodes that separate two stimuli increases. Studies have reported that emergent responding is an inverse function of number of nodes (e.g. Fields, Adams, Verhave, & Newman, 1990; Fields, Adams, Verhave, & Newman, 1993; Fields et al., 1997; Kennedy, 1991). Other scientists question whether such results actually are due to nodal number, and that it might be caused by variations in the experimental procedures used (e.g., Imam, 2001, 2006).

Imam (2001) found that when balancing the number of reinforcement contingencies to each trained relation and controlling for speed, the effect of nodes in emergent responding diminished. Imam replicated these results in 2006, arranging three different training protocols; simple-to-complex, complex-to-simple, and simultaneous, in a within-subject design. Results from this study show no function of the number of nodes, with regards to both response speed and accuracy, regardless of different training protocols (Imam, 2006). Also, Arntzen and Hansen (2011) reported similar results.

Directionality of training refers to the use of stimuli as sample and as comparison in training. Fields and Verhave (1987) offer three different variants of directionality in training: A→B, B→A, and A↔B. The two former variants are called unidirectional relations between stimuli, where one stimulus functions as a sample and the other functions as a comparison. The latter variant is called bidirectionality, where each stimulus is a sample in some trials and a comparison stimulus in others. Most studies establish unidirectional relations in training, which enables testing for symmetry. By training bidirectional relations, Spradlin and Dixon (1976) found that this results in higher yields in test for transitivity.

In three-node equivalence classes with five members (A→B→C→D→E) trained in LS, the A and E stimuli serve one function, sample and comparison, respectively. The nodes, B, C and D, serve dual functions in training, both as sample stimuli (conditional stimuli) in some trials and as comparison stimulus (discriminative stimuli) in other trials. In OTM participants have to match one sample stimulus to several comparison stimuli (A→B, A→C), whereas, in MTO, there are several sample stimuli that the participants have to match to one comparison stimulus (A→C, B→C). The main difference between MTO and OTM is that they differ in unidirectionality of training. In both training structures, each stimulus serve only one function in training, either as a conditional stimulus or as a discriminative stimulus, regardless of class size.

Sidman (1994) emphasizes with regards to directionality of training that the direction of the arrows when training conditional discriminations does not alter the training procedure. Any environmental difference functioning upon emergent responding, changes in directionality, does not affect the participants responding before experiencing the test for equivalence relations. If trained from A to B, participants have to successively discriminate between different sample stimuli, while simultaneously discriminate the comparison stimuli. When tested for symmetry, for example, a participant has to successively discriminate B stimuli which were previously simultaneously discriminated and vice versa with regards to the A stimuli. Sidman proposes that it might be switching from simultaneous to successive discriminations from training to test that have an effect on the behavioral properties of equivalence.

In an equivalence class consisting of five members the directionality of training can be varied in numerous ways, according to Fields and Verhave (1987). Their article lists some of the possibilities to how an equivalence class can be arranged with regards to variants of both unidirectionality and bidirectionality in training. In one of these variants, the directionality of training between stimuli is changed every other time; A→B←C→D←E. In such an arrangement each stimulus serve only one function in training; A, C, and E serves as sample stimuli or conditional stimuli and B and D serve as comparison stimuli or discriminative stimuli. How directionality of training and stimulus functions affect derived relational responding have yet to be fully elaborated and explored within the stimulus equivalence literature (Arntzen, 2012; Fields & Verhave, 1987). Comparing such an arrangement described above with an LS training structure, might be of interest as steps towards uncovering effects of directionality of training. Holding class size, distribution of singles, and the number of nodes constant, while directionality of training.

Reaction time between the occurrence of comparison stimuli and participants' selection and response to one comparison stimulus has been seen as a supplementary measurement to enrich the understanding of emergent responding (Dymond & Rehfeldt, 2001). Reaction times have been measured both in training and in test, and analyses reveal a repetitive pattern in reaction time when comparing the various relations. Studies show that when previously trained relations are presented in test reaction times are higher on those trials compared to when they were directly trained. Also, studies show an increase in reaction time from previously trained trials to symmetry trials, and an even further increase on equivalence trials (Arntzen, Braaten, Lian, & Eilifsen, 2011; Arntzen, Galaen, & Halvorsen, 2007; Arntzen et al., 2010; Arntzen & Hansen, 2011; Eilifsen & Arntzen, 2009; Spencer & Chase, 1996). Some researchers argue that reaction time measurements can be an indirect measure of precurrent and problem solving behavior arisen by the test (Arntzen et al., 2007; Holth &

Arntzen, 2000), whereas others see the repeated pattern in reaction time with regard to relation types as a direct function of nodal distance and confirmation that stimuli in an equivalence class are unequally related to each other (e.g. Moss-Lourenco & Fields, 2011). One interpretation of Sidman's big bag theory of stimulus equivalence, all equivalence relations are equally related and, therefore, reaction times should not vary in test for emergent relations (e.g., Sidman, 1994; Tomanari, Sidman, Rubio, & Dube, 2006).

The purpose of the present study was to investigate the effect of directionality of training on emergent responding, that is, the effect of stimuli serving as sample or comparison or both. The first goal was to compare two conditions which differed with regards to directionality of training in a mixed within subject and between groups design, counterbalancing the order of conditions. Differences between conditions were compared with regards to probability of responding in accordance to stimulus equivalence and the number of trials necessary to establish conditional discriminations. The second goal was to look at any differences in emergent equivalence relations with regards to the number of nodes. Finally, the third goal of the present study was to compare reaction time data for the two conditions with regards to relation types and nodes.

Method

Participants

The participants were 12 college students, 20 to 32 years old, three males and nine females. They were recruited through personal contacts. Participants 6201—6206 were randomly assigned in two conditions, so were participants 6207—6212 at a later time. There were six participants in each order of conditions, and all participants experienced both conditions. Participants were neither familiar with the experimental setting, nor the arbitrary relations between stimuli in the experiment, nor did they have any prior knowledge about stimulus equivalence. All participants signed a consensus form. Here, participants were informed that their results would be anonymous and that they could withdraw from the experiment at any time. After the experiment participants were thoroughly debriefed, and were shown their individual results. All participants received 300 NOK for participating in the experiment.

Settings

The experiment was conducted in 1.3 x 2.1 m and 1.2 x 2.6 m cubicles. In one cubicle the front and the right walls consisted of partitions, and on the back wall there was a window with an opaque curtain. The experimental cubicle contained a 1.2 m wide table with a computer and a small fan and a chair. In the other cubicle the left wall was of partitions and the cubicle contained a 1.2 m wide table with a computer, and a chair. Both the experimental cubicles were arranged to reduce possible confounding variables.

Apparatus and Stimuli

One EliteBook 8760w HP personal computer with an Intel Core i5-2540M CPU processor was used in this experiment. The computer had a 17 inch display. Computer software developed by Fields and Zhu was used to teach and test the conditional discriminations. In this experiment two sets of arbitrary stimuli were used. Both of the sets were randomly arranged and consisted of three five member classes of stimuli with a total of 15 stimuli in each set, see Figure 1. The number represents classes and the letters represent class membership. Stimulus set 1 was used in the linear series (LS) condition, and stimulus set 2 was used in the mixed directionality (MDIR) condition. On the screen the stimuli were presented on a white background, varying from 1.3 cm to 3.2 cm in size. The sample stimulus was always presented in the middle top part of the screen and the comparison stimuli were presented in the lower part of the screen, in a row. On the screen there were 17, 11, and 18.5 cm between sample stimulus and the three comparison stimuli, and there were 13 cm between the first and second comparison stimuli and 15 cm between the second and third. Programmed consequences consisted of written text, and were presented in the middle of the screen. Laminated printouts of the stimuli, used in both conditions, were given to the participant before each experimental condition. These printouts were the same size as the stimuli would appear on the screen.

Design

Present experiment was arranged as a mixed within subject and between group design, with two conditions counterbalanced. Participants were randomly assigned to the two orders of conditions and each individual were exposed to both conditions. The participants were trained with a linear series (LS) training structure in the LS condition and in the MDIR (mixed directionality) condition the participants received a training structure with mixed directionality of training.

Procedure

When arriving to the experiment participants were asked to read and sign an information sheet with a consent form. Here, the participants were informed that they were going to participate in an experiment on stimulus equivalence. Also, they were informed that they would be presented with different stimuli on a computer screen, that they would receive two conditions with a break between the conditions, that they could take more breaks if they wanted, and that the experiment would last approximately four to five hours from start to finish. The participants were given the information sheet in the experimental cubicle next to the experimental computer. After reading the sheet the experimenter emphasized verbally that their results would be anonymous and that they could withdraw from the experiment at any time. The participants were given the laminated stimuli from the stimulus sets belonging to the experimental condition they were going to be exposed to first, and were asked to categorize the stimuli as they felt like. A second set of laminated stimuli were presented before the second experimental condition. The experimenter wrote down how the participant categorized the laminated stimuli before both conditions, to ensure that the participants were not familiar with the experimental defined stimulus classes. After initial categorization the participants were faced with the computer and asked to read the instruction on the screen. Common information was given in both conditions:

> “In this part of the experiment you will be shown many tasks. Each task begins with a stimulus appearing on the screen, followed by the presentation of three other stimuli which are located at the bottom of the screen. Your task is to click on one of the stimuli on the bottom of the screen. When you do this you will get a feedback. Eventually you will get less and less feedback. When the stimulus appears on the top of the screen, press the key "A", and three other stimuli will appear. To press on the bottom left, press the key "1". To press the bottom center, press the key "2". To press on the bottom right, press the key "3". If you get the feedback "Correct", press "R". If you get the feedback "Wrong", press "W". If you get the feedback "No feedback", press "E". Try to get as many correct as possible. Tell the experimenter if you have any questions. If not, press "ENTER". Good Luck!”

Training. Participants 6202, 6203, 6206, 6207, 6209, and 6211 received the MDIR conditions first then the LS condition, for participants 6201, 6204, 6205, 6208, 6210, and 6212 the order of conditions were reversed. Common for both conditions, participants were trained in a simultaneous protocol, where all training trials were presented first following all test trials. Also, participants were presented with a serialized presentation of trials, where one relation was trained to a mastery criterion before presented with a new relation. See Table 1, for an overview of the experimental phases. Throughout training, participants were to match the stimuli simultaneously. In the LS condition the participants were trained in an LS structure and taught to match A to B, B to C, C to D, and D to E in three different classes. This was established after presentation of trials: A1<u>B1</u>B2B3, A2B1<u>B2</u>B3, A3B1B2<u>B3</u>, B1<u>C1</u>C2C3,

B2C1C2C3, B3C1C2C3, C1D1D2D3, C2D1D2D3, C3D1D2D3, D1E1E2E3, D2E1E2E3, and D3E1E2E3 (see Table 1). The first letter and number indicate sample stimulus and the underlined letter and number indicate correct comparison stimulus. In the MDIR condition the unidirectionality of training was changed and the participants were trained to match A to B, C to B, C to D, and E to D. This was done by presenting trials; A1B1B2B3, A2B1B2B3, A3B1B2B3, C1B1B2B3, C2 B1B2B3, C3B1B2B3, C1D1D2D3, C2D1D2D3, C3D1D2D3, E1D1D2D3, E2D1D2D3, and E3D1D2D3 (see Table 1). The manipulations of directionality of training in both conditions are illustrated in Figure 2.

Participants were presented with a sample stimulus in the middle of the top part of the screen, when pressing the letter “A” on the keyboard, three comparison stimuli were presented in the lower part of the screen, in a row. Participants had to press either “1”, “2”, “3” to respond to the comparisons to the left, middle, or right on the screen, respectively. If participants responded to the experimental defined correct stimuli the word “Correct” would appear on the screen. If the participants responded to the incorrect stimuli the word “Wrong” would appear. The programmed consequences remained on the screen until the participant pressed the letter “R” in the presence of “Correct”, and the letter “W” in the presence of “Wrong”. Immediately after responding to the programmed consequence a new sample stimulus would appear. In both conditions, each trial type was represented five times in each block, randomly. Participants had to reach a mastery criterion of 90% to continue to a new training phase, or a mixed phase. Not meeting the criteria in any of the phases led to a new block of trials until the mastery criterion was met. After reaching the mastery criterion in all the training phases, the programmed consequences with the word “Correct” or “Wrong” were reduced in three phases, with 75%, 25% and 0% probability of appearance contingent on responding. The words “Correct” or “Wrong“ were, in the reduction of programmed consequences phase, replaced with the words “No feedback” written on the screen after responding to a comparison stimulus and the participant had to press the letter “E” in its presence, prior to the appearance of a new sample stimulus. When reaching the criterion in the last phase with zero probability of programmed consequences the participants were immediately introduced to the test for stimulus equivalence.

Testing. During the test phase, participants experienced 60 previously trained relations (PTR), 60 symmetry trials (SYM) and 180 equivalence trials (EQ), with a total of 300 trials. In the LS condition half of the equivalence trials were trials testing transitivity, and the other half testing for global equivalence relations, which could not be differentiated in the MDIR condition, and therefore are referred to as equivalence trials. Out of all equivalence trials there were 90 trials testing one-node (1N) relations, 60 trials testing two-node (2N) relations and 30 trials testing three-node (3N) relations. All trials were randomly arranged throughout the test, and each trial ended with the words “No feedback” on the screen whereupon participants had to press “E” on the keyboard, after which a new sample stimulus appeared.

Second condition: training and testing. After the first training and testing, participants were offered a break, varying between 15 and 30 minutes. The participants were again placed in front of the computer and asked to categorize a new set of laminated stimuli. Participants went through the conditional discrimination training procedure and testing in the condition dissimilar to the previous.

Test trials responding. The MTS software recorded the participants responding. To meet the mastery criterion in the test participants had to respond correctly to at least 90% of the PTR, SYM, and EQ trials. Participants responded in accordance with stimulus equivalence when mastering the criterion for all relations in test was met.

After finishing both conditions the participants were fully debriefed and shown their individual results. Participants were also offered an introductory article about stimulus equivalence written by Dr. Arntzen.

Dependent variables. Number of trials used in training and percentage of correct responses on test trials were measured in this experiment. Reaction times were recorded from presentation of comparison stimuli to the occurrence of a response to a comparison stimulus. These variables were recorded by the MTS software. How the participants categorized the laminated stimuli before each condition was photographed and recorded by the experimenter.

Results

Overall, the results show that there is a higher probability of responding within the experimenter defined criteria for PTR and SYM trials in the MDIR condition compared to the LS conditions. Also, no systematic measure of accuracy was found with regards to the number of nodes on equivalence trials in either two conditions. Reaction time data displays an overall increase in reaction time from the directly trained trials in training to PTR in test, with a further increase on SYM trials, and an even further increase on EQ trials. Reaction times with regards to number of nodes show a dissimilar pattern across conditions and similar pattern within conditions.

Numbers of Trials to Criterion in Training

MDIR—LS. P6211 used 480 training trials in the MDIR condition, and with LS training structure the participant used 1215 numbers of trials in training, see Table 2. P6209 used 495 trials to criterion in the MDIR condition and 450 trials in the LS condition. In the MDIR P6203 used 1845 trials and 450 trials in the LS condition. P6207 used 585 and 450 trials in MDIR and LS condition, respectively. P6202 used 705 training trials in the MDIR condition, and with LS training structure the participant used 495 numbers of trials in training. P6206 used 510 and 435 trials in MDIR and LS condition, respectively.

LS—MDIR. When starting with the LS condition P6205 used 675 numbers of trials and 1065 trials in the MDIR condition, see Table 2. P6210 used 525 trials to criterion in the LS condition and 450 trials in the MDIR condition. In the LS condition P6204 used 720 trials and 555 trials in the MDIR condition. P6208 used 645 and 420 trials in the LS and MDIR, respectively. P6212 used 765 training trials in the LS condition, and in the condition with the MDIR training structure the participant used 465 numbers of trials in training. P6201 used 705 and 495 trials in the LS and MDIR condition, respectively.

Stimulus Equivalence Class Formation

MDIR—LS. Table 2 show that P6211 responded in accordance with stimulus equivalence on the test in the MDIR condition when testing PTR, SYM, EQ relations with result a of 97%, 100%, 98%, respectively. In the LS condition, the participant did not respond in accordance with stimulus equivalence, with a score of 87% for PTR, 80% for SYM relations, and 51% for EQ relations. P6209 responded 98% correct for PTR relations on test in the MDIR condition, 95% for SYM relation, and 85% for EQ relations. In the LS condition P6209 responded in accordance with stimulus equivalence, and responded 97% correct of the PTR, 93% on SYM trials, and responded on total 91% on equivalence trials. In the test after MDIR training, P6203 did not respond in accordance with stimulus equivalence, but had the previously trained and symmetrical relations intact, but not the EQ trials (87%). In the LS condition P6203 did respond in accordance with stimulus equivalence with an above criteria percentage in all relations. P6207 did only respond to the defined criteria in previously trained and symmetrical relations in test in both conditions, but not in equivalence relations. In the MDIR condition P6202 responded 95% for PTR, 93% in SYM, and at chance level EQ relations. In the LS condition the participant responded below mastery criteria for all relations. P6206 only responded above 90% for PTR trials in the MDIR condition, and under criteria for all other relations in both conditions.

LS—MDIR. When starting with the LS condition P6205 had the PTR intact but none of the other relations, and none of the relations were intact in test in the MDIR condition, see Table 2. P6210 had 90% correct trials for PTR trials in the LS and MDIR condition, but the participant did not meet the required criteria in the other relations in neither conditions. None of the remaining participants; 6204, 6208, 6212, and 6201, responded above experimental criteria for any of the relations in neither the LS condition nor the MDIR condition.

1-, 2-, and 3-node Emergent Relations

Figure 3 and 4, show percentage experimenter defined correct responding in 1-, 2-, and 3-node test trials for each participant. The results show no systematic decrease on percentage correct responding as a function of increased nodal number for equivalence trials. Figure 3 display those participants exposed to MDIR first, then the LS. Here, P6202 and P6206 test results shows an effect of nodal number when tested after the MDIR condition and P6205, P6207, and P6202 show this effect after trained in LS. The other seven test results do not show this effect. When the order of condition were reversed, see Figure 4, four test results show this effect after the MDIR condition; P6210, P6204, P6212 and P6201. The other eight test result does not show this effect. All in all, nine out of 24 test results can be interpreted as an inversed function of number of nodes. All of them had one, two, or all of the nodal relations around or under chance level (33.33%), and none of the relations were above 90% correct.

Reaction Times to Comparison Stimuli

A between-group analysis of reaction time has been done in the present experiment by calculating the mean median number of seconds participants used to respond to a comparison stimulus. Figure 5 shows the mean median reaction time to comparison stimuli, for all conditions across participants. Here, the last five directly trained trials, the first five PTR, SYM, and 1-, 2-, and 3-node EQ trials in test, and the last five PTR, SYM, and 1-, 2-, and 3 node EQ trials in test are displayed. The reaction times for the last five directly trained trials were, between 0.4 seconds (s) and 0.8 s, lower than the first five PTR trials in all conditions except when LS were presented as a second condition, where the reaction times were the same. In all conditions the reaction times for the first five trials increased from PTR trials to SYM trial between 1.4 s to 2.2 s, and there was a further increase in the first five trials for 1-, 2-, and 3 node trials. In the upper left part of the figure participants trained in the MDIR condition first are displayed, where mean median reaction time for the first five equivalence trials were 7.3 s for 1-node, 7.7 s for 2-node, and 6 s for 3-node trials. The upper right part of the figure shows mean median reaction time for the first five equivalence trials for participants trained in LS as a second condition, were 10.8 s, 9.4 s, and 8.6 s for 1-, 2-, and 3-node trials, respectively. The first five trials for 1-, 2-, and 3-node equivalence trials mean median reaction time for participants experiencing LS as a first condition were 5.4 s, 4.8 s, and 3,6 s, respectively, seen in the lower left part of the figure. The reaction times were 4.2 s for 1- node trials, 3.2 s for 2-node trials, and 2.8 s for 3-node trials for the same participant in MDIR conditions, seen in the lower right part of the figure. Reaction times for the last five directly trained trials are similar to reaction times for PTR trials in all condition, plus/minus 0.7 s. For participants trained in MDIR condition first reaction times were 2.1 s, 3 s, 3 s, 2.7 s, and 2.8 s for the last five TPR, SYM, 1-, 2-, and 3-node trials, respectively. The same participants trained in LS condition, the reaction time were 2.1 s for the last five TPR and around 3 s for the remaining relations. The mean median reaction time, for participants experiencing LS condition first, increased from the last five TPR to SYM trials, and increased further in 1-node trials, following and a decrease for 2-node trials, and even further decrease for 3-node trials. For the same participants trained in the MDIR condition the mean median reaction time was almost the same (varying 0.1 s) in all relations for the last five trials in test.

Discussion

The purpose of the present study was to investigate the effect of directionality of training as a property of training structure and stimulus function in conditional discrimination training, both in regards to equivalence class formation and trials to criterion. This was done by comparing two conditions in a mixed within subject and between group design. Another purpose was to look for any differences in emergent responding with regards to the number of nodes. Finally, the third purpose was to compare reaction time data between the two experimental conditions with regards to behavioral defined properties of stimulus equivalence and nodes.

With regards to the number of training trials necessary to learn all the conditional discriminations, there was no systematic difference between the conditions, or the order the conditions were presented in to the participants. This result might imply equally challenging training procedures in both conditions, and equally distributed reinforces.

Results from the present experiment show low yields in responding in accordance to equivalence classes when trained with a LS training structure, which replicates results of other experiments (e.g., Arntzen et al., 2010; Arntzen & Hansen, 2011; Arntzen & Holth, 1997, 2000a; Eilifsen & Arntzen, 2009; Fields, Landon-Jimenez, Buffington, & Adams, 1995; Fields et al., 1997). Also, present results might replicate previous research that show low probability of emergent responding, when sample and comparison stimuli are presented simultaneously compared to a delay between the offset of sample stimulus and onset of comparison stimuli (Arntzen, 2006; Bortoloti & de Rose, 2009; R. R. Saunders et al., 2005). Also, when responding on keys on a keyboard compared to responding with a computer mouse (Kato, de Rose, & Faleiros, 2008), and when using a simultaneous training protocol, compared to simple to complex or complex to simple protocols (Fields et al., 1997).

Present results show differential outcome on symmetrical relations as a function of variations of directionality of training. There was a higher probability of experimenter defined correct responding on previously trained trials and symmetry trials when conditional discriminations were trained with a training structure where unidirectionality of training varied every other time (A→B←C→D←E). Compared to a LS training structure where unidirectionality was the same in all trained relations (A→B→C→D→E). This effect was prevalent for participants exposed to the MDIR condition first and the LS condition second. Class size, number of nodes, and distribution of singles were held constant so the differences in results, with regards to previously trained trials and symmetry trials, may be attributed to manipulation of directionality of training.

Differential outcome on equivalence class formation as a function of directionality of training has been discussed in different ways. Sidman (1994) argue that any behavioral difference with regards to training structures may be attributed going from simultaneous to successive discrimination from training and test and vice versa. This assumption is supported by Saunders and Green (1999), who emphasize that successive discriminations are more difficult than simultaneous discrimination. To discriminate simultaneously among stimuli in the test that have previously been established with successive discrimination is, therefore, an "easier transfer". To discriminate successively between stimuli that have been established with simultaneous discriminations, is a "difficult transfer" (Arntzen & Vaidya, 2008). By this notion, it is a higher probability of equivalence class formation following conditional discrimination training with MTO compared to OTM.

In the present study, participants were tested with regards to the bidirectionality of the established relation when exposed to symmetry trials in the test. In symmetry trials, previously successively discriminated sample stimuli are required to be simultaneously discriminated. Previously simultaneously discriminated comparison stimuli in training are successively discriminated in test. In the present LS condition, stimuli A, B, C, and D functioned as sample stimuli in training (B, C and D functioned also as comparison stimuli), and were required to be successively discriminated in training and later simultaneously discriminated in test for symmetry, so called "easier transfers". The E stimuli functioned only as comparison stimuli, and necessarily had to be simultaneously discriminated in training, and required to be successively discriminated in test, so called “difficult transfer”. B, C and D stimuli were, necessarily, exposed to simultaneous and successive discriminations in training. In the MDIR condition, there were three “easy transfers” (stimuli A, C, an E) and two “difficult transfers” (stimuli B and D). Arguably, based on Sidman’s assumption, this should result in higher accuracy on symmetry trial in the LS condition than the MDIR condition. The results from the present study do not support this notion. Actually, the results show an opposite effect; there is a significant higher probability for derived symmetrical relations to emerge, subsequent the MDIR condition compared to the LS, with the proviso that the participants had no prior experience with a conditional discrimination training procedure. Sidman suggest that experiments might be conducted to investigate more explicit the effect of simultaneous versus successive discriminations, and how or if this is a critical variable in stimulus equivalence formation (Sidman, 2011).

According to Saunders and Green (1999), simple discrimination between stimuli is essential in matching to sample performance and stimulus equivalence class formation. The number of possible successive and simultaneous discriminations presented in training varies due to changes in unidirectionality of training. In MTO, participants are exposed to all possible simple discriminations necessary to form stimulus equivalence classes. In OTM and LS, participants are exposed to fewer numbers of possible simple discriminations resulting in lower yields when testing for equivalence properties after OTM and LS, then MTO (R. R. Saunders & Green, 1999). In a three 5-member stimulus class, participants are exposed all 105 possible simple discriminations when trained in MTO. When trained in LS or OTM, according to the simple discrimination account, participants are not exposed to 54 simple discriminations. In the present MDIR condition, using Saunders and Greens calculations, participants were not exposed to 36 simple discriminations. Based on the assumption that increased number of simple discriminations the participants are exposed to in training should increase the probability of forming equivalence classes, the MDIR condition should have had a higher outcome in test compared to LS. Also, the MDIR condition should yield higher outcome compared to OTM, which, when comparing present results to Arntzen and Hansen (2011) seems to not be the case. In that study, six participants established three 6-member stimulus classes in OTM, and all of them responded in accordance with stimulus equivalence.

Due to the arrangement of stimuli and the directionality of training in the MDIR conditions, there are similar features with both MTO and OTM. For example, when isolating AB and CB relations, they are similar to a MTO training structure, CB and CD relations are similar to OTM, and CD and ED are similar to MTO. With respect to the MDIR condition, one might have anticipated higher outcome on equivalence test trials, than what the results show, due to higher probability of forming equivalence classes when trained with MTO and OTM, than LS (Arntzen, 2012).

The probability of responding to experimenter defined transitive and global equivalence relations in both conditions, regardless of order, was low in the present experiment. Both the MDIR and the LS condition training structure consisted of three nodes; stimuli B, C, and D. This property separates the present MDIR condition with traditional MTO and OTM training structures. The low yields in LS replicate previous results (Arntzen & Hansen, 2011; Arntzen & Holth, 2000b; Fields et al., 1995; Fields et al., 1997), where the increased number of nodes decreases the probability of emergent responding compared to an increased number of singles. This might be the case in the present experiment.

According to the nodal distance approach emergent responding is an inverse function of the number of nodes that separate two stimuli (e.g., Fields & Verhave, 1987; Fields, Verhave, & Fath, 1984). Results from the present study show no systematic, so called nodal distance effect in regards to emergent responding. As displayed in Figure 3 and 4, nine out of 24 test results might be interpreted as an effect of nodal distance due to the downward pattern as the number of nodes increases. It is arguable whether those nine results actually can be analyzed as an effect of nodal distance, since one or all of the relations show accuracy at or below chance level of responding and none of the relations reach mastery criteria at 90%. The same argument has been raised by Lian and Arntzen (2013).

A four-term contingency is when a three term-contingency is under control of a conditional stimulus, and can be seen as the fundamental unit in conditional discrimination training and conditional stimulus control (Jones & Elliffe, 2013; Sidman, 1994). “The structure of the four-term unit reveals that conditional and discriminative control are different stimulus functions” (Sidman, 1994, p. 336), whereas discriminative stimuli are identified in relation to a differential response, while conditional stimuli does not need a response to be identified, it ‘selects’ a discriminator. The way directionality of training has been manipulated in the present experiment influences the number of stimulus functions each stimulus in the class has in training and in test. For example, in LS the A and E stimuli serve only one function, as a conditional stimulus and a discriminative stimulus, respectively, in their separate four-term contingency presented in training. Stimulus B, C, and D serve as conditional stimuli in some contingencies and as discriminative stimuli in others. In the MDIR condition directionality has been manipulated in such a way that each stimulus in a class serves only one function in training. Stimuli A, C, and E functions as conditional stimuli in training, and stimuli B and D functions as discriminative stimuli. Like the present MDIR condition, each stimulus in a class serve only one function in conditional discriminations trained with MTO or OTM, either as conditional stimuli or discriminative stimuli. Previous studies have found that there is a higher probability to respond to equivalence relations following conditional discriminations established in MTO and/or OTM training structure, than LS (Arntzen et al., 2010; Arntzen & Hansen, 2011; Arntzen & Holth, 1997, 2000a; Arntzen & Nikolaisen, 2011; Arntzen & Vaidya, 2008). Hence, one might attribute the high yields in previously trained and symmetry trials, in the MDIR condition, to the number of stimuli functions each stimulus serves in the conditional discrimination training; that the probability of responding to previously trained and symmetry trials under extinction reduces as stimuli serves more than one function in training.

Reaction times data show no differential effect between the two conditions in neither order these were presented. Overall, the reaction time results replicate previous findings that there is an increase in reaction time from training to test in previously trained relations, a further increase on symmetry trials in test, and an even further increase on equivalence trials (Arntzen et al., 2011; Arntzen & Hansen, 2011; Eilifsen & Arntzen, 2009). Reaction times for 1-, 2-, 3- node equivalence trials in the beginning of the test, across participants, show differential patterns in the two conditions. Average reaction times in both MDIR conditions are highest for 2-node trials and lowest for 3-node trials. In both LS conditions, reaction times for 1- node trials are higher than 2- and 3-node trials, where 3-node trials are lowest. Whether or not these differences in reaction time pattern are due to the manipulation of directionality of training is difficult to conclude with such a small number of participants.

Another nodal distance effect proposed by Fields in his colleagues (Fields & Moss, 2007), is that reaction times are a direct function of nodal distance, which means that participant's reaction time to comparison stimuli increase as the number of nodes that separate the two stimuli in the test trial increase. There is evidence supporting this effect on reaction time (Bentall, Jones, & Dickins, 1998; Fields et al., 1990). Results from the present experiment have not found this effect, and are in accordance to Imam's (2001, 2006) results, showing no effect of nodal distance, despite unequalized presentation of trials, as was done in Imam's experiments.

Two participants responded in accordance to stimulus equivalence following conditional discriminations training with LS as a second condition. There is a small increased probability for emergent relations to be formed when trained in LS as a second condition, compared to those participants trained with LS as the first condition. This difference might be attributed to an order effect; increasing the probability of accurately responding after a history with conditional discrimination training and testing emergent responding. This is in accordance with other studies using a within subject design in stimulus equivalence research (Arntzen et al., 2010; Arntzen & Vaidya, 2008). One interpretation of such a “positive” order effect might be that a participant learns some sort of problem solving behavior that is beneficial in the next condition.

An interesting result from the present experiment is that it seems to be the opposite result when the order of conditions is reversed, a “negative” order effect. Six out of six (100%) participants responded in accordance to the defined criteria for previously trained trials, and five out of six (83.3%) participants responded correctly on symmetry trials, whereas one out of six (16,6%) responded to criteria on previously trained trials when exposed to MDIR as a second condition and no participants (0%) met the criteria for symmetry trials. It seems that a history with the LS condition prior to the MDIR condition decreases the probability of responding to previously trained and symmetry trials drastically. This may be due to a history with LS that induce some sort of problem solving behavior that is unprofitable or nonfunctional when later tested in the MDIR condition. Why this happened is difficult to explain, and without more confirming evidence one cannot rule out that the present effect was simply due to coincidence. Either way, it might be of interest that the LS training structure not only diminish the possibility of establishing equivalence classes, but experience with LS has a negative effect in equivalence class formation later with another training structure. The value of uncovering the effect LS has on immediate and impending equivalence class formation might be of applied significance.

McIlvane, Serna, Dube, and Stromer (2000), suggest that unapparent behavior variability may be under control of other means than what experimenter intended, but still generated by the reinforcing contingencies arranged in the experiment. This may be especially evident when participants systematically respond inaccurately to the experimental defined relations. An example from the present study can be shown in Figure 3, where P6202 has zero percent accuracy for 3-node relations in the MDIR condition. To confirm this, one might look into which stimuli the participant selects when not selecting what was defined as correct in the present experiment. Unfortunately, the computer program used at present, did not allow for this detailed analysis.

There are some limitations in the present study that could be eliminated in further research. First, including a condition with MTO or OTM structure might be beneficial when researching the effect of directionality of training and stimulus function with the two present conditions. This might also be advantageous as to rule out other possible sources accountable for the low outcome on equivalence trials in the present study, since these two structures generally yields higher outcome on equivalence trials (e.g., Arntzen, 2012). Second, increasing the number of participants in each order of conditions could ensure a more powerful conclusion of the behavioral effect of the manipulation. Third, a more detailed computer software, measuring which comparison stimuli the participant responds to when not responding correctly, might reveal that the participant's behavioral repertoire is under some sort of conditional stimulus control different from what was intended by the experimenter.

Further research on the effect of directionality of training may include different combinations of unidirectionality and bidirectionality, proposed by Fields and Verhave (1987), to get an in depth understanding of stimulus function in conditional discrimination training, and the effect training structures have on equivalence class formation. One suggestion might be to replicate the training structure used by Kennedy (1991), where participants were trained AB, AC, BD, BE, CF, and CG relations. Here, stimuli were arranged in such a way that it had properties of both the OTM and LS training structures. In the analysis of the experiment, Kennedy (1991) focused on emergent relations and nodes, and did not look into detail at the effect of directionality of training and the conditional discrimination training was conducted as a table top procedure and not on a computer. Also, in the study by Fields et al. (1997), they use different training structures that might be interesting to replicate with regard to exploring directionality of training. As with the Kennedy study, the analyses were focused on nodes and emergent relations. For example, in the Fields et al. study, in one condition the training structure is made of these relations; AB, BC, DB, and BE. Here, features of all three training structures are incorporated in one arrangement, adding another level of complexity, which may be an interesting future study in understanding the effects of directionality of training.

In conclusion, results from the present experiment show that manipulating the directionality of training affects the probability to respond correctly on previously trained relations and symmetry trials in test. With an increased probability of correct responding when conditional discriminations were trained in a structure with mixed directionality of training compared to a LS structure. Also, there seems that different manipulation of directionality of training affects reaction time data with regards to one-, two-, and three-node relations differentially. Present study reveals no effect of nodal distance in regards to accuracy, or reaction time. Further expansion and elaboration of the complexity in class formation, and the effect different arrangement of conditional discrimination training has on equivalence class formation, might have great value both conceptually and applied.

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Table 1

Overview of Experimental Phases

Phases	Trial Types, Condition LS	Trial Types, Condition MDIR	Number of trial types	Minimum # of Trials	Programmed Consequences (%)
Training Phase 1	AB	AB	3	15	100
Training Phase 2:	BC	CB	3	15	100
Mixed Phase 1+2	AB, BC	AB, CB	6	30	100
Training Phase 3:	CD	CD	3	15	100
Mixed Phase 1+2+3	AB, BC, CD,	AB, CB, CD	9	45	100
Training Phase 4	DE	ED	3	15	100
Mixed Phase 1+2+3+4	AB, BC, CD, DE	AB, CB, CD, ED	12	60	100
Training Phase 5 Fading programmed consequences	AB , BC, CD, DE	AB, CB, CD, ED	12	60	75
Training Phase 6 Fading programmed consequences	AB , BC, CD, DE	AB, CB, CD, ED	12	60	25
Training Phase 6 Fading programmed consequences	AB , BC, CD, DE	AB, CB, CD, ED	12	60	0
Test Phase	**Previously Trained Relations**				
	AB, BC, CD, DE	AB, CB, CD, ED	12	60	0
	Symmetry				
	BA, CB, DC, ED	BA, BC, DC, DE	12	60	0
	Equivalence				
	AC, AD, AE, BD, BE, CE, EA, EB, EC, DA, DB, CA		36	180	0

Note. MDIR = mixed directionality, LS = linear series

Table 2

An Overview of the Results

	MDIR				LS			
P	# tr trials	PTR	SYM	EQ	# tr trials	PTR	SYM	EQ
6211	480	**97**	**100**	**98**	1215	87	80	51
6209	495	**98**	**95**	87	450	**97**	**93**	**91**
6203	1845	**97**	**98**	87	450	**100**	**100**	**98**
6207	585	**100**	**95**	27	450	**100**	**92**	57
6202	705	**95**	**93**	34	495	88	83	24
6206	510	**90**	87	25	435	63	62	35
	LS				**MDIR**			
P	# tr trials	PTR	SYM	EQ	# tr trials	PTR	SYM	EQ
6205	675	**93**	83	34	1065	78	68	36
6210	525	**90**	68	32	450	**90**	85	62
6204	720	88	85	66	555	83	85	38
6208	645	87	77	29	420	83	83	32
6212	765	78	78	22	465	85	72	67
6201	705	73	55	38	495	42	33	27

Note. P = participant number, # tr trials = number of training trials to criterion, PTR = previously trained relations, SYM = symmetry trials, EQ = equivalence trials. MDIR = mixed directionality condition, LS = linear series condition. Bold letters represent responding in accordance to the mastery criteria of 90% correct.

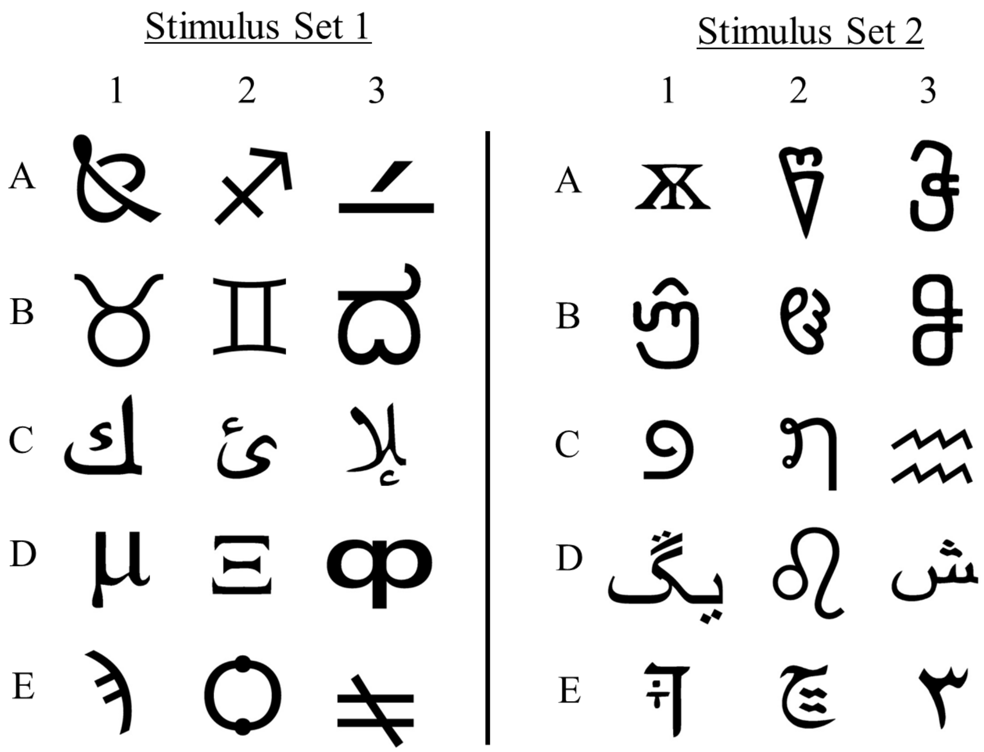

*Figure 1.*The two stimulus sets used in the experiment. The numbers indicates different stimulus classes and letters indicates class membership.

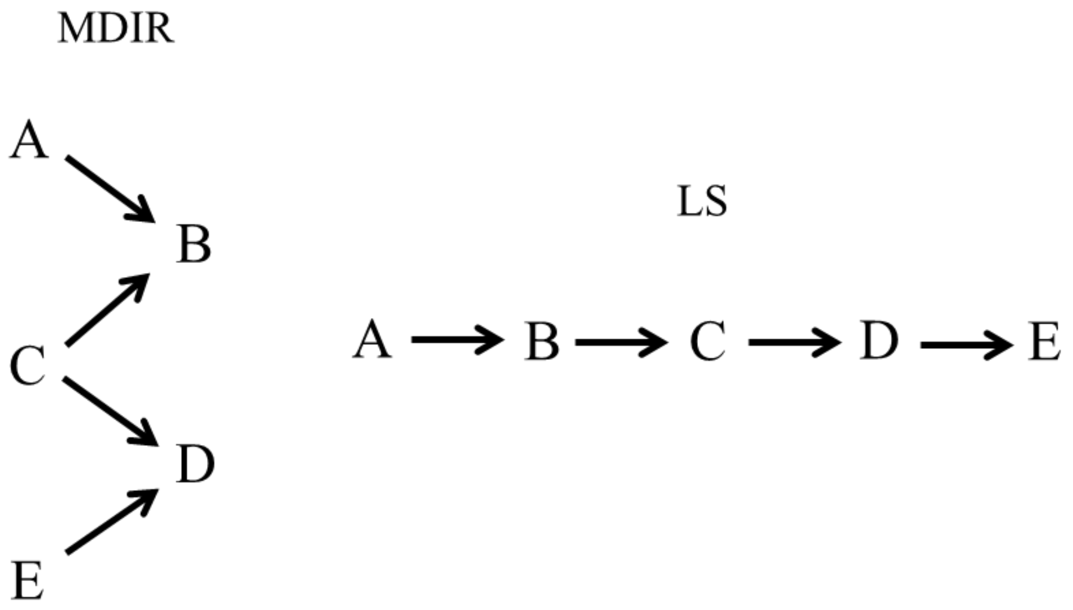

Figure 2. The directionality of training in both mixed directionality (MDIR) condition and in linear series (LS) condition is illustrated.

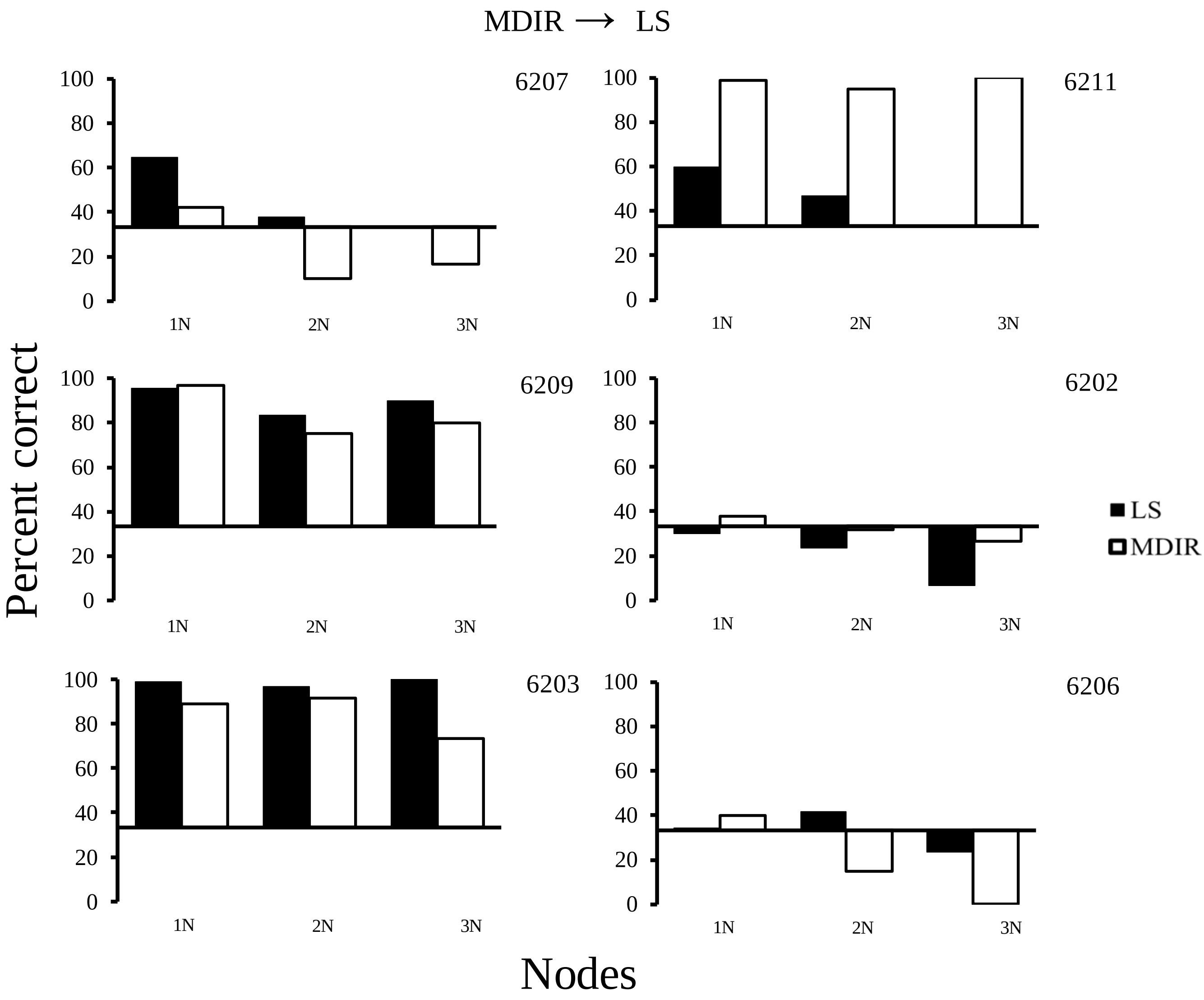

*Figure 3.*Percent correct responding on test trials with different nodal numbers separating the two presented stimuli. One-, two-, and three-node trials are denoted 1N, 2N, and 3N, respectively. Results from participants first experiencing the mixed directionality condition (MDIR) then the linear series condition (LS), are displayed. White bars indicate MDIR condition and black bars indicate LS condition.

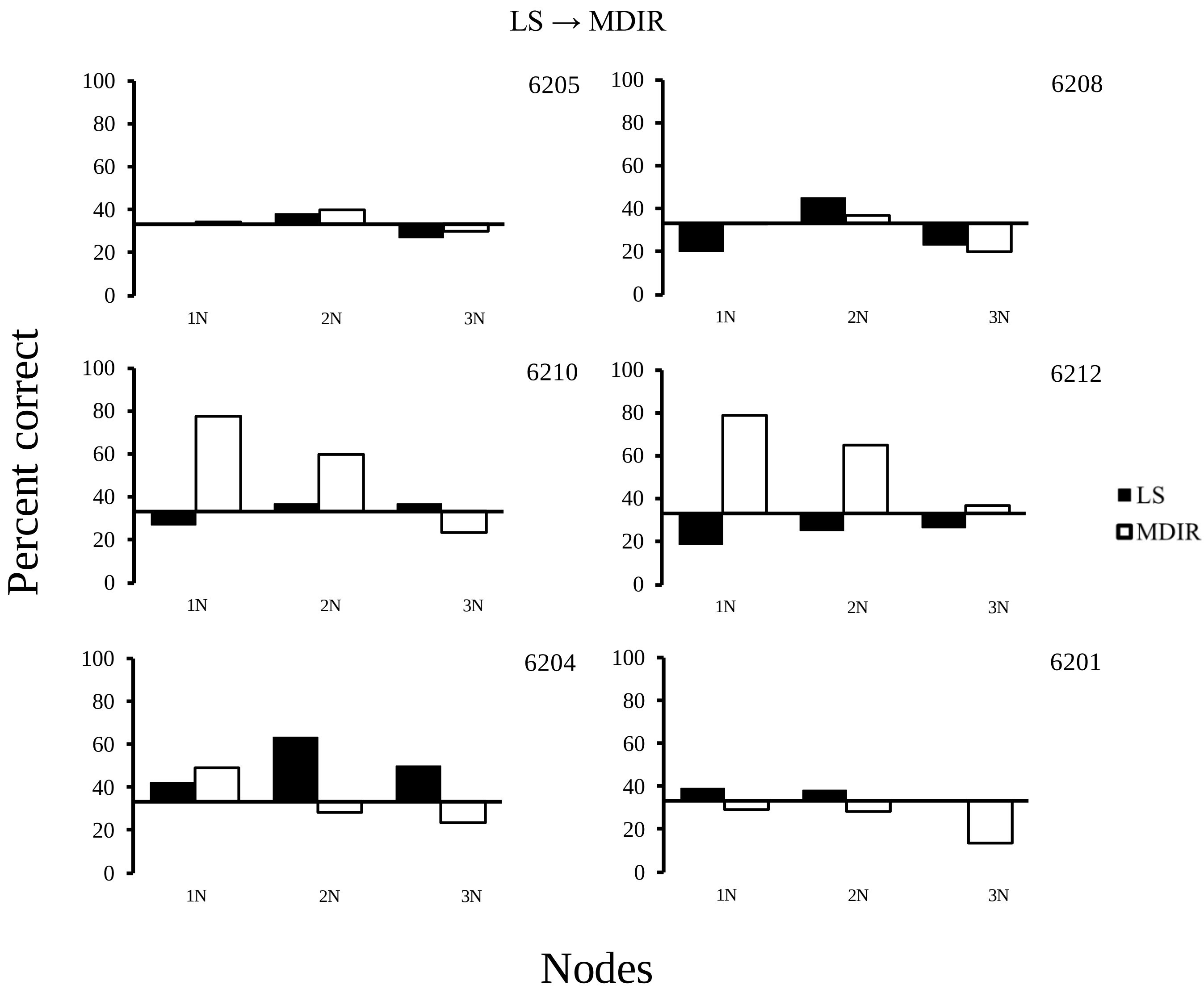

*Figure 4.*Percent correct responding on test trials with different nodal numbers separating the two presented stimuli. One-, two-, and three-node trials are denoted 1N, 2N, and 3N, respectively. Results from participants first experiencing the linear series condition (LS) then the mixed directionality condition (MDIR), are displayed. White bars indicate MDIR condition and black bars indicate LS condition.

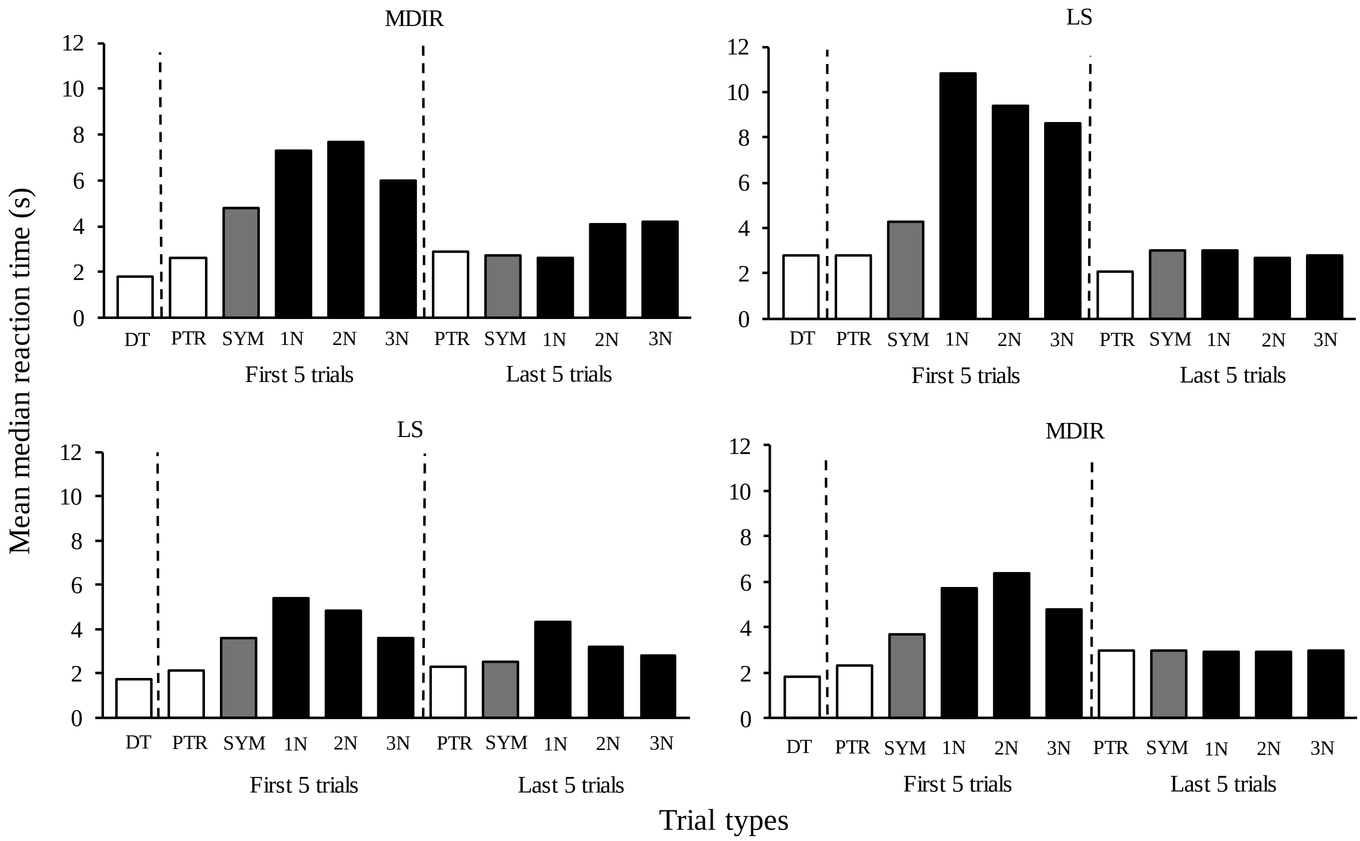

Figure 5. The mean median reaction time across participants in each condition, for the last five training trials (DT), previously trained relations in test (PTR), symmetry trials (SYM), and one-, two-, and three-node equivalence trials (1N, 2N, and 3N, respectively). Upper part of the panel display reaction time data for groupof participants starting with MDIR condition (left graph) then experience LS condition (right graph). Lower part of the panel displayresults for the group of participants starting with LS condition (left graph) then the experience the MDIR conditions (right graph).