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Main title:

Stimulus Equivalence: A Conceptual and Empirical Investigation of Generalizations of Abstract Stimuli: Does Proximity Equal Equivalence?

Article I – Theoretical article:

Different Behavioristic Philosophical Assumptions and Different Interpretations of the Nodal Distance Effect

Article II – Empirical article:

Differences of the Nodal Distance Effect in Sorting Tests after Different Matching-to-Sample Protocols

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Kort sammendrag

Stimulusekvivalens kan definers som emergens av nye relasjoner uten direkte forsterkning etter at kondisjonal diskriminasjon er etablert, der nye relasjoner kan bli beskrevet i form av refleksivitet, symmetri, og transitivitet. Slike emergente relasjoner sies å representere "likhet" mellom stimuli, selv om de er topografisk ulike. Nodeavstandshypotesen er en hypotese om stimulusekvivalens der respondering i henhold til emergente kondisjonale relasjoner minker som en funksjon av en økende antall noder. En node er en stimulus som "binder" respondering i henhold til to eller flere kondisjonale diskriminasjoner og som muliggjør transitivitetsrelasjoner. For eksempel, en kan etablere kondisjonale diskriminasjoner ved en differensiell forsterkning av relasjonene AB, BC, og CD, der dette kan lede til forekomsten av nye relasjoner AC og AD. AC relasjonen har B stimulus som en node og AD relasjonen har stimuli B og C som noder. AC er 1-node relasjon og AD er en 2-node relasjon. Prediksjonen til hypotesen er at respondering i henhold til AC relasjoner forekommer med større sannsynlighet enn AD relasjoner. Artikkel I i denne oppgaven undersøkte konseptuell problematikk angående hypotesen. Dette var gjort ved å undersøke vanlige filosofiske antagelser for forskjellige former for behaviorisme og forskjellige behavioristiske tilnærminger for å gjentolke nodeavstandshypotesen. Artikkel II undersøkte empirisk problematikk angående hypotesen. Dette ble gjort ved å undersøke hvordan forskjellige målinger av respondering i henhold til nye relasjoner blir endret av antall noder.

Emneord: node avstand, stimulusekvivalens, behaviorisme, simultan, enkel-til-kompleks, sortering, alternative målinger

Short summary

Stimulus equivalence can be defined as emergence of new relations without direct reinforcement after conditional discrimination is established, as these new relations can be described by reflexivity, symmetry, and transitivity. Such relations are said to represent "sameness" of the stimuli, despite having different topographies. The nodal distance hypothesis is a hypothesis about stimulus equivalence whereas responding in accordance with emergent conditional discrimination decreases as a function of increasing numbers of nodes. A node is a stimulus that "connects" responding in accordance with two or more conditional discriminations and occasions for transitivity relations. For instance, one can establish conditional discrimination by differential reinforcement of the relations AB, BC, and CD, as this may lead to the occurrence of new relations AC and AD. The AC relation has B stimulus as one node and the AD relation has stimulus B and C as nodes. The AC relation is a 1-node relation and the AD relation is a 2-node relation. The prediction of the hypothesis is that responding in accordance with AC relations occurs with larger probability than AD relations. Article I in this paper investigated conceptual issues regarding the hypothesis. This was done by investigating common philosophical assumptions of different forms of behaviorisms and different behavioristic positions to reinterpret the nodal distance hypothesis. Article II investigated empirical issues regarding the hypothesis. This was done by investigating how several measurements of responding in accordance with new relations are changed by number of nodes.

Keywords: nodal distance, stimulus equivalence, behaviorism, simultaneous, simple-to-complex, sorting, alternative measurement

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Different Behavioristic Philosophical Assumptions and Different Interpretations of the Nodal Distance Effect

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Abstract

Once conditional discrimination is established, emergent conditional discrimination tends to occur which have the defining properties of reflexivity, symmetry, and transitivity. The nodal distance hypothesis is a hypothesis about emergent conditional discrimination which states that emergent conditional discrimination decreases as number of nodes increases. A node is a stimulus that "links" other stimuli in emergent conditional discrimination. For instance, by training AB, BC, and CD, the following transitivity relations may occur: AC and AD. The AC relation is "connected" by one node (stimulus B) and the AD relation is "connected" by two nodes (stimulus B and C). Although emergent conditional discrimination decreases as nodal number increases, the nodal distance hypothesis suggests that the cause is due to the increase in nodal number and not functional variables. Structural variables are rarely used as explanations in behavior analysis. In this paper, different behavioristic philosophical positions are used to evaluate and reinterpret the nodal distance effect. Specifically, interbehaviorism, radical behaviorism, teleological behaviorism, theoretical behaviorism, and functional contextualism is used to reinterpret the nodal distance effect and further conceptual issues of the nodal distance effect is investigated.

Keywords: nodal distance, interbehaviorism, radical behaviorism, teleological behaviorism, theoretical behaviorism, functional contextualism

Different Behavioristic Philosophical Assumptions and Different Interpretations of the Nodal Distance Effect

"Ipsa scientia potestas est" [Knowledge itself is power] (Bacon, 1597) is perhaps one of the quotes that truly defines the nature of mankind. It is knowledge that has enabled mankind to cooperate, to form civilizations, and develop technologies that further strengthens the survival of our and other species. Oxford dictionary defines knowledge (2019) as facts, information, and skills acquired through experience or education; the theoretical or practical understanding of a subject. Skills, experience, or education are events that are often complex and hard to define in an observable manner. However, what is considered facts and information for an individual is even harder. Another word which is closely associated with facts, information, and skills is the word "concept". The word concept is traditionally defined as abstract ideas that occurs in the mind and is the fundamental building blocks of our thoughts and beliefs (Margolis, Eric, & Stephen, 2019). In layman's terms "having the right concepts" may help us further develop appropriate knowledge about the world. However, ideas, the mind, and thoughts are often dualistic in nature making them hard to investigate through a natural scientific lens.

The aim of this paper is to describe how concept formation can be investigated by the stimulus equivalence paradigm, how generalizations of abstract stimuli occurs or becomes a part of a stimulus equivalence class, and how different types of behaviorism can be used to interpret how such generalizations occur. Specifically, this paper will discuss the nodal distance hypothesis, which is a hypothesis about such generalizations, and how the nodal distance effect can be examined through interbehaviorism, radical behaviorism, teleological behaviorism, theoretical behaviorism, and functional contextualism paradigm in order to provide new perspectives on how the nodal distance effect can be analyzed. *Handbook of Behaviorism* (O'Donohue & Kitchener, 1999) will be the primary source for the different types of behaviorisms and where external sources will be added for further investigation of a given topic.

Stimulus Equivalence

Stimulus equivalence can be defined where different stimuli acquire the same function despite being physical different. The term “stimulus equivalence” has been used differently in different context, for instance, by Hull (1939). However, contemporary definitions of stimulus equivalence are mostly based on Murray Sidman’s definition, where the emergence of new relations occurs during conditional discrimination as the defining properties are based on *reflexivity*, *symmetry,* and *transitivity* (Sidman & Tailby, 1982). Conditional discrimination is a type of stimulus control where the presence of some stimuli (referred to as sample stimuli) changes the functions of other stimuli (referred to as comparison stimuli) (MacKay, 1991).

Conditional discrimination is often studied by using a matching-to-sample (MTS) procedure. During an MTS procedure, a sample stimulus (Sa) is first presented, followed by several comparison stimuli (Co) as one of the comparison stimuli functions as a discriminative stimulus for responding (Co+), and where the other stimuli functions as a stimulus-delta (Co-). By presenting a stimulus (A1) as a Sa and by presenting several Cos (B1, B2, and B3) where only one functions as a Co+ (B1), one can implement a differential reinforcement procedure for responding during such stimuli relations, which results in an increase of responding during such stimuli relations (noted as A1B1 trial). These relations are referred to as baseline relations or trained relations. In the presence of another stimulus (A2) as a Sa and by presenting several Cos (B1, B2, and B3; where B2 is Co+), one can again establish a conditional discrimination of the relation A2B2. When A1 is presented as a Sa then B1 functions as a Co+ while other Cos functions as Co-, and when A2 is presented as Sa then B2 functions as a Co+ while other Cos functions as Co-. Thus, Co is determined to function as a Co+ or Co- by the Sa. The numbers in, for instance, an A1B1 trial refers to the stimulus class and the letter refers to their membership. One can also further use a set of Cos as a Sas for other stimuli in that class as a way to expand the class by, for instance presenting a Sa B1 and presenting C1, C2, and C3 as Co, where C1 is the Co+.

Once all the Sas and Co+s (e.g., all the Sas A and the Co+s B are trained, and all Sas B and Co+s C are trained, are noted as AB and BC) are trained, then emergent conditional discrimination may occur either where the responding in context of other stimuli are related to themselves without direct reinforcement (if A then A, if B then B…, also known as reflexivity), where responding during Sa and Co occurs when reversed order without direct reinforcement (if AB, then BA, also known as symmetry), or where as after two conditional relations are trained, then responding occurs when a stimulus in one conditional relation is related to a stimulus in another relation without direct reinforcement (If AB and BC, then AC, also known as transitivity). Combined symmetry-transitivity refers to having both the properties of symmetry and transitivity without direct reinforcement (if AB and BC, then CA). These emergent conditional relations without reinforcement are investigated by test trials. An everyday example would be that a child may learn that in the presence of the written word “CAT” (A) as Sa, several pictures of animals are presented (Cos) and whereas the picture of a cat (B) functioning as a Co+, one can train the child for pointing at the picture of a cat by a differential reinforcement procedure. Later, the picture of a cat (B) is presented as a Sa and the spoken word /cat/ (C) function as a Co+ is also directly reinforced. Once this occurs, children tend to respond in accordance with reflexivity (if A then A), symmetry (if AB then BA), transitivity (if AB and BC, then AC), and combined symmetry-transitivity (if AB and BC, then CA). In layman’s terms, the child is said to “know”, “understands” that these stimuli “are the same” or “has formed a concept” of what a cat is.

Nodal Distance

The nodal distance hypothesis is a hypothesis about stimulus equivalence formation which states that emergent conditional discrimination decreases as the nodal number increases (Fields & Verhave, 1987). A node is a stimulus that “connects” other stimuli which occurs in transitivity relations and combined symmetry-transitivity relations. For instance, by training AB and BC, an AC transitive relation may occur. A and C is “connected” or have both been used as functional stimuli in relation to the B stimulus. The B stimulus is a node; thus, the AC relation is a 1-node transitivity relation. Similar, by training AB, BC, and CD, an AD transitive relation may occur where the B and C stimuli acts as two nodes; thus, the AD relation is a 2-node transitivity relation. The nodal distance hypothesis would predict that after an AB, BC, and CD training condition, responding in accordance with AC relations would occur more frequently than AD relations during test conditions. There exist several theoretical accounts of the nodal distance effect, such as *the contingency account*, *the naming account*, and *the discrimination analysis* (Fields & Moss, 2007).

According to the contingency account, emergent conditional discrimination is a function of the reinforcement history of previous trained conditional relations. Imam (2006) investigated the nodal distance hypothesis in the context of different MTS training and testing protocols. The three most common MTS training and testing protocols are the simultaneous, simple-to-complex, and complex-to-simple protocol. A simultaneous MTS protocol consists of first training all the baseline relations (e.g., AB, BC, and CD) and then testing all of the non-trained relations that consist of the same stimuli that were used in training (which is also referred to as a mixed test, e.g., BA, DC, CA, …,). A simple-to-complex MTS protocol consists training baseline relations and, when available, tests for symmetry, transitivity, and combined symmetry-transitivity classes in that order followed by a mixed test. For instance, by training AB, then the symmetry relation BA is tested. This would be followed by training of baseline relations of AB, and BC, and tested for symmetry CB. Later, all of the baseline relations would be trained (e.g., AB and BC), where all of symmetry relations will be tested (e.g., BA and CB), then all of the transitivity relations will be tested (e.g., AC) followed, combined symmetry-transitivity test (e.g., CA). At last, presenting all non-trained relations. A complex-to-simple protocol consist of training baseline relations, then test for combined symmetry-transitivity relations. If the participants did not respond accordance with combined symmetry-transitivity trials, then transitivity is tested. If the participant did not respond in accordance with the transitivity test, then symmetry is tested, and followed by testing all of the non-trained relations. Imam's (2006) results shows that the nodal distance effect was not found when one were to equalize the amount of reinforcers and baseline trials in across the protocols. Simple-to-complex protocols will produce more conditional discrimination training trials on stimuli that are first presented in a class rather than the relations that are directly trained later in that class. For instance, by training the following relations by a simple-to-complex protocol AB, BC, CD, and DE, AB is trained firstly trained, and BA is tested. Next, AB and BC are trained, and CB is tested. Later, AB and BC are trained, symmetry, transitivity, and combined symmetry-transitivity relations are tested in that order, followed by a mixed test. Later CD is trained, and DC is tested. At last, AB, BC, and CD is trained. Thus, the baseline relations AB and BC are trained more often compared to CD. Imam (2006) concluded that the nodal distance effect was due to non-equalized training trials and not due to the structural variables. If emergent conditional discrimination was to decrease as a function of an increasing nodal number, then emergent conditional discrimination should do so with equal training and testing trials.

The naming account builds on the assumption that humans tend to produce bidirectional speaker-listener interactions and that such interactions may be responsible for emergent conditional discrimination (Horne & Lowe, 1996). For instance, a participant may respond in accordance with a functional equivalence class (e.g., objects) and where such stimuli set the occasion for speaker behavior (a common name for the objects). Later, the speaker behavior (the common name) may be a discriminative stimulus for listener behavior for the same stimuli in the previous functional equivalence class (the previous objects). As interpreted by Moss and Fields (2007), stimuli in a class may occasion the same name and where the same name acts as a node that further sets the occasion for all the stimuli in the class. The authors conclusion was that the nodal distance hypothesis is not compatible with naming, because in accordance with the naming account, there exists no more than one node relations. However, Bentall (1998) proposes that each internodal link could require mediating responses that sets the occasion for the next node and that such responses may be naming. Tomanari, Sidman, Rubio and Dube (2006) investigated this idea by setting up an MTS training and testing procedure while decreasing the limited-hold of the responses gradually, while not decreasing accuracy of responding below 90% during baseline. By using this procedure, one could rule out naming being responsible for mediating responses between nodes by analyzing how fast participants responds in accordance with stimulus equivalence. Tomanari et al. (2006) concluded that responding in accordance with stimulus equivalence were fast enough (usually below 1 s) and unlikely caused by mediating responses. Arntzen and Haugland (2012), replicated the previous study but added an titration schedule, which investigated changes in reaction time on Co stimuli, and by changing the limited hold on Co stimuli to a fixed 1.2 s limited hold. Their results show that despite as the reaction time increases, emergent conditional discrimination did not change as a function of increasing nodes.

The discrimination analysis account takes the training structure into consideration, which can influence stimulus equivalence formation. During an MTS training procedure, one can set up a training procedure in accordance with a one-to-many structure (e.g., AB, AC, AD, …), many-to-one structure (AD, BD, CD, …), and linear series structure (AB, BC, CD,

…). Saunders and Green (1999) proposes that the discrimination analysis account builds on the assumption that (a) there are interactions between simultaneous and successive discriminations in a MTS procedure, (b) the frequency of simple discrimination presentations to the participants is critical for stimulus equivalence formation, and (c) the absence of control by exclusion regarding simple discrimination is a necessary components for stimulus equivalence formation. The author also proposes that only the many-to-one training structure (where AB, AC, AD, and so on is trained) presents all the simple discriminations for positive outcomes and not discriminations by exclusion. In addition, Sidman (1994) and Imam (2006) suggests that a linear series training structure (where AB, BC, CD, and so on) is preferred for investigating the nodal distance hypothesis. As proposed by Wang, McHugh, and Whelan (2012), the discrimination account implies that the nodal distance effect is an artifact of the training procedure itself. The authors set up an MTS training procedure with a linear series of 5-members 2-classes (AB, BC, CD, and DE) and investigated whether emergent conditional discrimination was predicted by either the discrimination analysis account or by the nodal distance account. The discrimination analysis account would predict that those stimuli which are repeatedly trained both as sample and comparison would emerge before than those stimuli who are lack such training. In this training condition, stimuli B, C, and D are being trained more often as both Sa and Co+ compared to stimuli A and E. Thus, BD or DB emergent conditional responding would occur at the highest rate and AE or EA at the lowest rate based on the training. Other relations (e.g., AC, CA …) would produce moderate emergent conditional responding despite having different nodal number. The results of the study show that the participants responding were better predicted by the nodal distance hypothesis compared to the discrimination analysis account.

The contingency account, the naming account, and the discrimination analysis account are theories that have contributed to empirical investigations of stimulus equivalence formation and the nodal distance effect. However, the naming and discrimination analysis does not specify their philosophical assumptions about the nodal distance effect neither if the nodal distance effect are caused by structural or functional variables. A structural approach would suggest that the nodal distance effect is primarily caused by the number of nodes as described by Fields and Verhave (1987). This type of explanation is based on what Holth (2013) refers to as disposition-based (or summary label) or a "behavioral" internal mediating mechanism-based. For the disposition-based explanations, a glass may break because of "its brittleness". Disposition-based explanations occurs where an object (e.g., a glass) is categorized by several other similar objects (e.g., other glasses) and where similar objects are predicted by a common event (e.g., breaks when impacted by relatively little force compared to other solid objects). However, these explanations summarize descriptions and does not refer to functional variables that causes the phenomena (what caused the glass to break, e.g., a stone). Internal mediating mechanisms are detailed disposition-based explanations. In the previous example and in accordance with the internal mediating mechanism-based explanation, the glass broke because of its covalent molecular bonds. Similarly, the number of nodes is an internal mediating mechanism that predicts the decrease in emergent conditional discrimination, but it does not point to events that causes the nodal distance effect. A functional approach would suggest that the nodal distance effect is not caused by the number of nodes but caused by external variables rather than internal as suggested by Sidman (1994). The nodal distance effect should be investigated through functional variables where the nodal distance effect is a dependent variable, and not where the nodes acts as independent variable for emergent conditional discrimination. By using functional variables, one can even investigate whether the emergent conditional discrimination may decrease or even increase as the nodal number increases depending on what variables are acting upon the given effect. It may thus more appropriate to refer to these effects as nodal-modulating effect. However, there exist other behavioristic philosophical positions that have not been used to account for the nodal distance effect. These different paradigms can be used to provide new conceptual approaches and may facilitate a wider array of empirical research regarding the nodal distance effect. Thus, general behavioristic philosophical assumptions, different types of behaviorisms, their unit of analysis will be introduced, and used to interpret the nodal distance effect.

Behaviorism

Behaviorism can be defined as the philosophy of a natural science of behavior in both nonhuman animals and human animals (Skinner, 1976). It is hence not a science, but there exist sciences that builds on behavioristic assumptions. According to Zuriff (as cited in O'Donohue & Kitchener, 1999), nearly all different types of behaviorism share 13 assumption. These points will later be used to compare the different behaviorisms.

1. Psychology is a branch of natural science. As proposed by Watson (1913), psychology should be viewed as an experimental branch of natural science, where behavior is the subject matter, and that methodologies used in the physical sciences can be used in the study of behavior. Cooper, Heron, and Heward (2013) suggests that the purpose of a natural science is the ability to describe, predict, and control phenomena, which is behavior in this case, and that natural science builds on the assumptions of determinism, empiricism, experimentation, replication, parsimony, and philosophical doubt. An important note is that different levels of parsimony and philosophical doubt may be the two central assumptions of natural science that contributes to a wide range of behaviorisms.

2. Psychological evidence should be objective. Objective evidence may differ from tradition to tradition; however, a common agreement of objectivity among the behaviorisms is that it is rooted in the natural sciences, and thus, emphasizes physical descriptions and quantitative measurements. As mentioned by Zuriff (1985), criteria for behavioral data should be based on an emphasis on physical descriptions of the related phenomena, an action based

language, where behavior is described by function or topography, and done so at an appropriate level of analysis which is either molecular or molar for the subject matter.

3. Introspection should be avoided. As Skinner (1976) suggested, an individual's verbal behavior of its private events is largely shaped and maintained by its verbal community. Hence, private events do not necessarily control public verbal reports of such behavior. Skinner (1957) speculates that the environment can shape verbal reports about one's own private events through public accompaniment, collateral responses, common properties, and response reduction, although whereas using such events as explanations is problematic.

4. Psychological data should be based on molar behavior and not physiological processes. Depending on what is considered behavior, sciences that builds on behavioristic traditions often focuses on relative molar behavior (this includes molecular and molar behavior in behavior-analytic terminology) compared to physiological processes.

5. Mentalism is to be avoided. Rejection of mentalism as a valid strategy for scientific investigation is central for nearly all behaviorisms. The word "mentalism" have its origin from the word "mental", which refers to activities caused by "the mind" (Baum, 2017). Mentalism is where behavior or the physical phenomena in general are explained by referring to the mental (an assumed separate world, substance or property), which is often assumed to be non-physical, and is maybe impossible to investigate due to the lack of determinism, observability and objectivity of the phenomena that is regarded in the realm of the mental. Mentalism is also in an opposition for several assumptions of this list.

6. Theoretical concepts should be grounded in behavioral data. Theoretical concepts are meant to be used to study behavior and not other phenomena. Other scientific fields may use behavior as a medium for observing other phenomena (such as feelings, memory, or cognition) while a science of behavior is focused on how changes in behavior occur.

Phenomena that are usually classified as feelings, memory or cognition can also be classified as behavioral phenomena.

7. A focus on behavior-environment relations. According to most behaviorisms, behavior should be studied by its contextual variables and not by its structure. However, what is considered as environment in behaviorism is different from what is considered environment by other scientific fields. The environment in a behavioristic approach can be defined as parts of the universe that itself is not the behavior of study and parts of one's body may be considered an environment for one's behavior (Skinner, 1976). However, a problem arises when one cannot control private events through experimental manipulations. Thus, it is better to investigate environmental events that can be manipulated experimentally, and such events often occurs outside the skin of the organism.

8. Adaption to the environment is emphasized. Learning is central in behavioristic theories, which can be defined as a relative permanent change of actions based upon prior experiences (Catania, 2013), and where learning is often naturalized as prior behavior-environment interactions. Behavioristic theories do not equate to tabula rasa theories. For instance, biological behaviorism and behavioral ecology investigates phylogenic variables of behavior. However, the most dominant behavioristic approach is the ontogenetic approach to study behavior, although such theories does not exclude phylogenic variables.

9. Speculations of cognitive processes often hinders behavior-environment investigation. Watson's behaviorism initially started out as a reaction against the methods used in psychology, where most psychological investigation at that time focused on a deductive approach to non-observable phenomena (such as consciousness) that are assumed to influence behavior. The avoidance of cognitive processes has been continued in several behaviorisms and naturalization (or behavioralizations) of cognitive processes are rather preferred.

10. Rejects internal causes of behavior. As mentioned by the 7th and 9th assumption, behavioristic traditions often focus on behavior-environment relations and often steers away from speculations of cognitive processes. This is primarily due to avoid mentalism. Explanatory fictions and category mistakes are two types of mentalistic reasoning. (Baum, 2017). Explanatory fictions occur as the explanation of a behavior is referred to an assumed but non-observable event. Category mistakes (Holth, 2001) occurs when different phenomena are given a common name and where one assumes that the common name is the cause of the individual phenomena.

11. Mentalistic constructs can be translated into behavior-environment relations. There exists different expressions or phrases which describes and explains behavior that are used in our daily lives. However, some of those labels are often mentalistic in nature and assume that there is an agent within the individual that causes behavior. For instance, people are said to "have self-control" when people choses long-term strategies and assumes that those long-term strategies are caused by the self-control. In a behavioristic perspective, self-control is the long-term strategies and caused by environmental variables, rather than stating that self-control is the causing variable for long-term strategies.

12. Language can be explained through investigation behavior-environment relations. Some theories of language are based on that there is a correspondence between arbitrary words or symbols selected by a culture and that individuals refers to such events when they use them. However, Skinner's (1957) approach is to rather define interactions between individuals as functional, specifically how a speaker influences a listener. This is an example of how behavior-environment relations can be used to explain language.

13. Philosophical questions should be naturalized. Though experiments are rarely used in behavior analysis. It is however common to operationalize terms such as "self-control",

"concept formation" or "problem solving" in clearly defined behavior-environment relations and interactions.

Different Types of Behaviorisms

Interbehaviorism

Interbehaviorism (Hayes & Fredericks, 1999; Kantor & Smith, 1975) is a type of behaviorism that sees behavior-environment relations as the unit of analysis which cannot be analyzed into their parts and emphasizes the analysis of the whole organism through interbehavioral fields. The interbehavioristic position agrees with all of the previous assumptions for behaviorism, except some of the 7th point. Although interbehaviorism agrees that behavior-environmental relations are central for the study of behavior, it however does not "break apart" the behavior-environment relations in order to do so because responses are defined by the stimuli which they are defined by, and vice versa. Thus, the unit of analysis is the response-stimulus (or stimulus-response) relations and referred to as interbehaviors. In addition, interbehaviorsim may be viewed as transdisciplinary, ranging across different levels of analysis although having the interbehavioral field as its fundamental unit of analysis.

The interbehavioral field consists of organismic factors, stimulational factors, interbehavioral history, media of contact, and setting factors. The organismic factor can further be categorized into responses and response functions. Responses are categorized by their topography, while response functions are several responses which shares common functions, despite having different topographies. The stimulational factors can further be categorized into stimuli and stimuli functions. Similarly, stimuli can be defined in terms of their physical properties or defined on how their effect responses. The interbehavioral history refers to the accumulation of previous interbehavioral fields which may be equivalent to the term learning history used in behavior analysis. The media of contact refers to events that "connects" the response function and stimulus function. For instance, pigeons may discriminate between green and red color. However, this may not occur if there is no light that illuminates the colors. Visible lights in this context acts as a media of contact for the colors of green and red. The setting factors refers to external events that changes response-stimulus relations. This term may be equivalent to conditional discrimination or motivating operations. In addition, different interbehavioral fields can be categorized as universal, idiosyncratic, cultural or basic behaviors. *The universal behaviors* are actions that all individual shares through common biological and natural properties of the stimulus object. These behaviors are often classified as “unconditioned” behaviors in other behaviorisms. *The idiosyncratic behaviors* are the behaviors that are acquired through their ontogenic factors. *The cultural behaviors* are action that all individuals share through common ontogenic factors as several individuals share a same response function of common stimuli objects (which is referred to as cultural stimuli). *The basic behaviors* are the fundamental forms of actions which are acquired early through ontogenic factors.

Based on an interbehavioristic approach, one can analyze if the nodal distance effect could be analyzed through (a) different factors participating in the interbehavioral field or (b) which interbehavioral category does the nodal distance effect fit to. Several responses and response functions (accuracy, reaction time, transfer of function, or other yet unknown dimensions) should decreases as number of nodes across several stimuli and stimuli function increases, and the interbehavioral history would be needed to control for confounding variables. One interpretation is that the media of contact is gradually “weaken” as the number of nodes increases even though the stimuli functions of the stimuli is the same and that the media of contact is the nodal number. The setting factors, such as conditional discrimination, motivating operations, and verbal behavior may all influence the nodal distance effect. The nodal distance effect could be classified either by universal, cultural, basic interbehavior or a combination of all of them. If the nodal distance effect is assumed to be a universal interbehavior, then nodal distance effect may be best be interpreted by phylogenic factors and can be considered a basic behavioral process, similar to how Sidman (1994) suggests that stimulus equivalence is a basic behavioral process as further analysis is not needed. While the nodal distance effect has been reported several times, its influencing factors are still needed to be further investigated to determine if the nodal distance effect is influenced by ontogenetic variables or not. Similar argument can be used for the assumption that the nodal distance is a cultural interbehavior (best viewed as changed by ontogenic factors) or basic interbehavior (best viewed as acquisition of early interbehaviors which causes exponential learning, e.g., language).

Radical behaviorism

Radical behaviorism (Moore, 2008; Ringen, 1999) as a stance in philosophy of behavior assumes that non-observable phenomena such as thoughts, feelings, and motivations are behaviors, differ only by the degree of observability, that such private events are equivalent to public events, and are thus, under influenced by the same variables. However, using private events as causes for behavior is problematic for the radical behaviorists because they are not observed directly. Thus, radical behaviorism favors parsimonious approach to the study of behavior by minimizing theory-driven research (Skinner, 1950), prefers the usage of the inductive method, investigating functional variables rather than structural variables, and emphasizes an selectionistic approach. Radical behaviorism does accept with all assumptions of behaviorisms. However, the 2nd, 6th, and 7th assumptions tends to be more emphasized compared to other behaviorisms. The behavior-environment relations which is central is respondent or operant behavior where the three-term contingency is used as the fundamental unit of analysis of behavior, which describes the relation between preceding stimuli, responses, and consequences which is followed (S-R-S).

Responses, consequences, stimuli, respondent behavior, operant behavior, reinforcement, punishment, and discriminated operants (Catania, 1991) are central concepts for investigating observable behavior-environment relations. A response is an instance of a given behavior of the organism. Johnston and Pennypacker (2009) defines behavior as "… that portion of an organism's interaction with its environment that involves movement of some part of the organism (p. 46). A consequence is an event that is produced by a given response. A stimulus is an event that is classified as an aspect of the environment for a response. Respondent behavior is behavior which are controlled by preceding stimuli. Operant behavior is behavior which probability is controlled by its behavior-consequence relation. Operant behavior can be categorized in to the descriptive definition of operant behavior, and the functional definition of operant behavior (Catania, 1973). The descriptive definition refers to the procedures and the functional definition refers to the outcome of such procedures. Reinforcement as a procedure is the delivery of consequences after a given response, whereas functionally results in an increase of those responses, and that those responses increases due to the response-consequence contingency. Punishment has the same criteria, but where the responses decreases. Discriminated operants are operant behaviors which have been differentially reinforced in the presence of a preceding stimuli (SD) which responding produces reinforcement and not during their absence (S-delta) descriptively, which results in responding in the presence of SD and not S-delta functionally. In addition, Skinner (1981) suggests that selection happens (a) phylogenetic, (b) ontogenetic, and (c) cultural level. However, radical behaviorism tends to focus on ontogenetic level and that prior concepts can be used to investigate such phenomena.

Radical behaviorism would interpret the nodal distance effect as caused by functional variables. Sidman (1994) suggests several critical factors for evaluating the nodal distance hypothesis. Firstly, the distance in nodal distance may be interpreted as a hypothetical entity (which is avoided in radical behaviorism) that describes some form of "associative strength" between different emergent conditional discriminations may be misleading and that he proposes that number of nodes is more appropriate label. Another important point is that reflexivity, symmetry, and transitivity all are the defining properties of stimulus equivalence, and that one can have same number of nodes while having different symmetry-transitivity combinations. For instance, by training AB, AC, and DC, the BD and DB have the same number of nodes. However, BD requires that both AB and DC baseline relations produces the symmetry relations of BA and CD. The DB requires only transitivity (DC is already trained, and CA emerges). Thus, one needs to account for increasing nodal number while keeping the requirements for stimulus equivalence equal. A third point is how other functional phenomena are affecting the nodal distance effect, such as verbal behavior (e.g., rule-governed behavior). A forth point is that a stimulus equivalence class has members that are substitutable for each other and that the nodal distance hypothesis suggests that they are not. In order for the nodal distance hypothesis to be valid one may need to redefine stimulus equivalence by other terms than reflexivity, symmetry, and transitivity. In addition, members of a stimulus equivalence class are defined by the context which they occur in and where such members may also belong to other classes. For instance, one can teach a participant to select a Co+ of its color and regardless of its shape when a Sa is presented. When a red square is the Sa and Cos are a red circle, a green triangle and a blue square, the participants is directly trained to select the red circle. Later, one can teach a participant to select Co+ of its shape regardless of color. When a red square is the Sa and Cos are red circle, green triangle, and a blue square, the participant selects the blue square. If one were to again expose the participant for the first condition of color matching, the Sa is a red square and the Cos are red circle, green triangle, and blue square. The Cos red circle and blue square now belong to the same class due to prior training. These interactions can contribute to the differential emergent conditional discriminations across different members of a class.

Teleological Behaviorism

Teleological behaviorism (Rachlin, 1999) is a type of behaviorism that emphasizes on molar analysis of behavior rather than molecular analysis of behaviors, suggests that private events are often localized in a wider behavior-environment relation, that correlations between responses and stimuli over time is preferred rather than studying the temporal aspects between responses and stimuli, and that behavior may be controlled by their utility functions. Teleological behaviorism focus on final causes of behavior in contrast to radical behaviorism as efficient causes is central. The behavior-environment relations that are central in teleological behaviorism is several operant behaviors over extended in time, often through the use of behavioral distribution as a function of environmental variables. Efficient causes are events that changes an individual operants such as reinforcement, punishment, discrimination etc., while final causes are events that changes a set of several operants over time. For instance, one can analyze efficient causes during concurrent two variable-interval (conc VI VI) schedules of reinforcement (Pierce & Cheney, 2013) by analyzing each response-consequence relation. However, one can analyze final causes during conc VI VI schedules by observing the interaction of two operants during one schedule compared to the other schedule, such as through the matching law proposed by Herrnstein (1961). Teleological behaviorism may not agree completely with the 5th, 9th, and 10th assumption of behaviorism. The teleological behavioristic approach to phenomena that are considered mental events is that they in fact occur in a wider environmental context. Thus, private events are viewed as not yet observed behavior-environmental relations that occurs on a molar level of analysis (Rachlin, 2013). For instance, thinking of a chess move does not occur inside the individual but occurs in a wide environmental context of several chess matches as some of those strategies have been reinforced over time.

In accordance with this philosophical position, teleological behaviorism may interpret the nodal distance effect as caused by functional variables. Based on a teleological behavioristic approach, one can analyze the nodal distance effect through temporally extended behavioral patterns by investigating emergent conditional discrimination by higher repeated testing trials, and not by less repeated test trials. A higher degree of repeated testing trials can be used to analyze the nodal distance effect by (a) accuracy, (b) reaction time, (c) transfer of function, (d) and post-class formation within-class preference tests can be evaluated at a molar level rather than a molecular level. A common finding in stimulus equivalence research is the phenomena referred to as delayed emergence (Sidman, 1994) which is where emergent conditional discrimination tends to increase when participants are repeatedly exposed for test trials. In accordance with teleological behaviorism, delayed emergence can be viewed as temporally extended behavior, and if the nodal distance hypothesis were to hold then it should occur during delayed emergence. As mentioned by Fields and Moss (2007) delayed emergence can produce a “celling effect” where emergent conditional discrimination of 1-node, 2-node, and 3-node relations may all be emitted at maximum value when measured.

However, there are some studies that have measured the nodal distance effect across measurements by delayed emergence. Fields, Adams, Verhave, and Newman (1990) trained AB, BC, and tested emergent conditional discrimination. After the participants emitted the celling effect, then they were trained CD relations. In accordance with the nodal distance hypothesis, 1-node relations of BD and DB should occur more frequently than the 2-node relations of AD or DA measured by accuracy, despite having tested trials that had presented the D stimuli equally. The results show that the 1-node relation emerged before the 2-node relation, which supports the nodal distance hypothesis measured by delayed emergence. The nodal distance effect measured by reaction time by delayed emergence have also been investigated. Bentall et al. (1998), and Spencer and Chase (1996) found the nodal distance effect in the beginning of the test trials (which is referred to as immediate emergence) but not by delayed emergence. These results do not support the nodal distance hypothesis measured by delayed emergence. A third way of evaluating the nodal distance effect by delayed emergence is by transfer of function tests. Fields, Adams, Verhave, and Newman (1993) trained 5-member, 2 classes (AB, BC, CD, and DE) and tested for stimulus equivalence classes. Later, the participants who responded in accordance with stimulus equivalence were also trained differential responses to A1 and A2. Thereafter, transfer of function was evaluated. The results show the nodal distance effect during immediate emergence and not by delayed emergence. These results do not support the nodal distance hypothesis measured by delayed emergence. Sorting tests can be used to evaluate the nodal distance effect where the participants may sort the stimuli in accordance with the nodal structure of the class. Arntzen et al. (Arntzen, Granmo, & Fields, 2017) documented that three out of 11 participants who formed stimulus equivalence classes also sorted in accordance with the nodal structure. In accordance with the nodal structure, one of the participants sorted during pre-sorting and post-sorting tests, a second participant sorted three out of three classes during pre-sorting and two out of three classes during post-sorting test, and a third participant sorted only during the pre-sorting classes, which further supports previous studies that the nodal distance effects usually occurs during immediate emergence. These results do not support the nodal distance hypothesis measured by delayed emergence.

Theoretical Behaviorism

Theoretical behaviorism (Staddon, 1999; Staddon, 2014) is a type of behaviorism that focuses on constructing models that can predict behavior-environment relations, that the model is the behavior of the organism, that there exists internal states that effect behavior but that such internal states are influenced by prior behavioral history, and that investigation of prior behavioral history can be used to study internal states. Theoretic behaviorism would not agree with the 10th assumptions of behaviorism. Theoretical behaviorism avoids mentalism by searching for lawful parsimonious models which can predict behavior. Theoretical behaviorism differs from cognitivism where behavior is the subject matter and not used to study other processes, uses theoretical concepts that are based on behavioral data such as equivalent behavioral history, and internal states are taken into consideration to predict behavior rather than to explain mental phenomena. In theoretical behaviorism, the behavior-environment relation is formulated a formal description of relations of behavior-environmental interactions. For instance, pigeon A may be exposed for a conc VI VI schedule where the right schedule is a VI-5 s and the left schedule is an extinction (EXT) schedule, and later changed such that the right schedule is an EXT schedule and the left a VI-5 s. Pigeon B may be exposed for a conc VI VI schedule where the right schedule is a EXT schedule and the left is a VI-5 s. At this stage, the behavior of the pigeons is similar as they both allocate their behavior more on left. However, during an EXT of both schedules, the pigeon A will have different behavioral allocation than pigeon B. The teleological behavioristic stance would argue that behavior should be investigated by a molar analysis, which is in this case to consider all of prior conditions and not only the last EXT condition. Theoretical behaviorism investigates such equivalent learning history across participants and assumes that such equivalent learning history affects the internal states of the organism. In addition to the previous example, the number of reinforced trials on one schedule may affect the change of responding when the schedules are switched which is known as reversal learning. For instance, obtaining 10 reinforcers for one schedule, 0 for the other, and then changing the order of the schedules will produce different responding if the schedules were based on every 20th obtained reinforcer. The cumulative effect model which can be expressed through the following formula: VLeft = (RLeft + RL0) / (xLeft + XL0) is a model of how responses are allocated after different amounts of reinforcement by conc VI VI schedules during extinction. VLeft is the response strength of responding on the left schedule, RLeft is the total number of reinforcers obtained for the left schedule, xLeft is the total number of responses on left; XL0, and RL0 are constants which represents the animal's initial tendency to respond to either left or right. This model is an attempt to predict how animals would respond (VLeft) if they shared the same values of XLeft, XL0, RLeft, and RL0. However, the constants are theoretical constructs and non-observable.

Based on this philosophical position, theoretical behaviorism may consider the nodal distance effect as a structural variable, which is what is proposed by Fields and Verhave (1987). In accordance with theoretical behaviorism, the nodal distance effect could be described by a model. Firstly, a model for the establishing of discriminated operants is needed. As proposed by Davison and Nevin (1999) one can construct a model of discriminated operant based on many assumptions. The question whether the discriminated operant based on simultaneous discrimination or concurrent schedules, or the amount of reinforcement all influences stimulus control. All of these considerations need to be investigated. Secondly, a model of conditional discrimination is also needed. The Davison-Nevin model of conditional discrimination performance (1999) which builds upon behavioral momentum theory and signal-detection theory can be used as a foundation. At last, models that would predict outcomes of emergent conditional discrimination would be needed at a more general level and experimental studies would later investigate whether models that uses constants based only on the nodal number (which is what the nodal distance hypothesis states) would result in a decrease of emergent conditional discrimination, or whether the nodal distance effect is caused by other variables than the nodal number. In other words, simpler models of emergent conditional discrimination are necessary first before investigating the nodal distance effect by such models. There are some attempts by using artificial intelligence-based computer models for emergent conditional discrimination (Ninness, Ninness, Rumph, & Lawson, 2018), although it is still necessary to investigate empirically whether such models are parsimonious or not, and if they are able to predict behavior.

Functional Contextualism

Functional contextualism (Gifford & Hayes, 1999) is a type of behaviorism which purpose is to develop an organized system of concepts that are based from empirical investigation, where such investigations are used to predict, and influence behavior with precision, depth, and scope. Influence is used in functional contextualism rather than control as it does not include the criteria of minimizing variability or complete avoidance of confounding variables. Prediction and influence are achieved by precision, scope, and depth. Precision refers to where a relative few analytic tools are used to study any event, scope is where several phenomena can be analyzed by using such analytic tools and depth is where such analytic tools are coherent with other levels of natural science. Functional contextualism does not necessarily agree with any of the assumptions, is only concerned with the function of hypothesis and theories of behavior, and if they can describe, predict, and influence behaviors. The exists no central behavior-environment relations in functional contextualism, all behavior-environment relations that either predicts or influences future behavior are investigated in basic or applied settings.

The nodal distance hypothesis in accordance with this philosophical position may be evaluated based on either its pragmatic value or whether the hypothesis satisfies the criteria of precision, scope, and depth. The nodal distance hypothesis may have a pragmatic value. The nodal distance hypothesis may influence how one views learning mechanisms in humans, despite of the hypothesis being correct or not. If applied studies used the nodal distance hypothesis to arrange training structures that takes into consideration of the nodal structure of a given stimulus equivalence classes because of its high social validity and it may have a pragmatic value. For instance, if one were to teach a child a stimulus equivalence class of “spoken numbers”, “presenting different quantities of objects”, “written numbers”, and “numerical representation of numbers” in that order, it may matter practically if the “spoken numbers” has fewer nodal numbers related to “written numbers” compared to “numerical representation of numbers”. In some situations, some emergent conditional discrimination is “more important” than others based on social factors. Another consideration is that the nodal distance effect as a label would be more appropriate when it comes to describing the phenomena rather than explaining them by the nodal distance hypothesis may be the case based on the assumptions of behaviorism. However, the nodal distance hypothesis may influence scientists or practitioners of other fields to implement such interventions better than by labeling it as the nodal distance effect. In other words, it may be “easier” to “understand” the nodal distance hypothesis where decrease in emergent conditional discrimination occurs due to increasing number of nodes rather than the nodal distance effect where emergent conditional discrimination decreases as number of nodes increases due to yet unknown variables. This approach is however more concerned about the behavior of the scientists or practitioners, rather than to investigate the phenomena. As for the phenomena only, the functional contextualistic position would favor a functional approach for the nodal distance effect.

The nodal distance hypothesis may not satisfy all of the criteria of precision, depth, and scope. When it comes to precision, the nodal distance hypothesis is a new proposed behavior principle that is suggested, although the nodal distance effect can also be explained by other variables such as differences in training and testing trials, or verbal behavior. When it comes to scope, the nodal distance hypothesis may be used to analyze a wide range of events. The nodal distance hypothesis scopes all events that requires emergent conditional discrimination, where emergent conditional discrimination may be used to analyze important and complex human behavior what would be described in layman's term as language, concept formation, and memory. When it comes to depth, the nodal distance hypothesis is in accordance with other sciences, such as computational sciences and set theory. However, as pointed by Sidman (1994), the defining properties of reflexivity, symmetry, and transitivity are terms from set theory which used to describe emergent conditional discrimination, and are not used as explanations for them. It remains yet an empirical question whether increasing the nodal number causes a decrease in emergent conditional discrimination.

Summary and Further Implications

This paper has described the defining properties of stimulus equivalence, its basic research methods, the nodal distance effect, the nodal distance hypothesis, its empirical research, the basic philosophical stance of behaviorism; how interbehaviorism, radical behaviorism, teleological behaviorism, theoretical behaviorism, and functional contextualism emphasizes on some other philosophical aspects than others, and how the nodal distance effect is interpreted by them. The behavioristic positions mentioned generally favors a functional approach for studying behavior, except for theoretical behaviorism. Further investigations of the nodal distance effect through other measurements are needed and further empirical investigations should focus in how the nodal distance effect is caused by functional variables, rather than defining its structural mechanisms. Thus, our ability to gather knowledge about the world should be based on that our concepts are more influenced by the context which they occur in rather how concepts are influenced by other prior concepts.

References

Arntzen, E., Granmo, S., & Fields, L. (2017). The relation between sorting tests and matching-to-sample tests in the formation of equivalence classes. *The Psychological Record, 67*(1), 81–96. doi:10.1007/s40732-016-0209-9

Arntzen, E., & Haugland, S. (2012). Titration of limited hold to comparison in conditional discrimination training and stimulus equivalence testing. *The Psychological Record, 62*(2), 243–261. doi:10.1007/BF03395800

Bacon, F. (1597). *Meditationes sacrae*: Excusum impensis Humfredi Hooper.

Baum, W. M. (2017). *Understanding behaviorism: Behavior, culture, and evolution*(Third ed.).

Bentall, R., Jones, R., & Dickins, D. (1998). Errors and response latencies as a function of nodal distance in 5-member equivalence classes. *The Psychological Record, 49*(1), 93–115. doi:10.1007/BF03395309

Catania, A. C. (1973). The concept of the operant in the analysis of behavior. *Behaviorism, 1*(2), 103–116. Retrieved from http://www.jstor.org/stable/27758804.

Catania, A. C. (1991). Glossary. In I. H. Iversen & K. A. Lattal (Eds.), *Experimental analysis of behavior: Part 2* (pp. G1–G44). Amsterdam: Elsevier.

Catania, A. C. (2013). *Learning* (5th ed. ed.). Cornwall on Hudson, N.Y: Sloan Publishing.

Cooper, J. O., Heron, T. E., & Heward, W. L. (2013). *Applied behavior analysis: Pearson new international edition* (2th ed.): United Kingdom: Pearson Education M.U.A.

Davison, M., & Nevin, J. A. (1999). Stimuli, reinforcers, and behavior: An intergration. *Journal of the Experimental Analysis of Behavior, 71*(3), 439–482. doi:10.1901/jeab.1999.71-439

Fields, L., Adams, B. J., Verhave, T., & Newman, S. (1990). The effects of nodality on the formation of equivalence classes. *Journal of the Experimental Analysis of Behavior, 53*(3), 345–358. doi:10.1901/jeab.1990.53-345

Fields, L., Adams, B. J., Verhave, T., & Newman, S. (1993). Are stimuli in equivalence classes equally related to each other? *The Psychological Record, 43*(1), 85–105.

Fields, L., & Moss, P. (2007). Stimulus relatedness in equivalence classes: Interaction of nodality and contingency. *European Journal of Behavior Analysis* 141–159. doi:10.1080/15021149.2007.11434279

Fields, L., & Verhave, T. (1987). The structure of equivalence classes. *Journal of the Experimental Analysis of Behavior, 48*(2), 317–332. doi:10.1901/jeab.1987.48-317

Gifford, E. V., & Hayes, S. C. (1999). Functional contextualism: A pragmatic philosophy for behavioral science. In W. T. O'Donohue & R. Kitchener (Eds.), *Handbook of behaviorism* (pp. 285–327): Academic Press.

Hayes, L. J., & Fredericks, D. W. (1999). Chapter 3: Interbehaviorism and interbehavioral psychology. In W. O'Donohue & T. Kitchener (Eds.), *Handbook of behaviorism* (pp. 71–96). University of Nevada, Reno: Academic Press.

Herrnstein, R. J. (1961). Relative and absolute strength of response as a function of frequency of reinforcement. *Journal of the Experimental Analysis of Behavior, 4*(3), 267–272. doi:10.1901/jeab.1961.4-267

Holth, P. (2001). The persistence of category mistakes in psychology. *Behavior and Philosophy, 29*(1), 203–219.

Holth, P. (2013). Different sciences as answers to different why questions. *European Journal of Behavior Analysis, 14*(1), 165–170. doi:10.1080/15021149.2013.11434454

Horne, P. J., & Lowe, C. F. (1996). On the origins of naming and other symbolic behavior. *Journal of the Experimental Analysis of Behavior, 65*(1), 185–241. doi:10.1901/jeab.1996.65-185

Hull, C. L. (1939). The problem of stimulus equivalence in behavior theory. *Psychological Review*, *46*(1), 9-30. doi:10.1037/h0054032

Imam, A. A. (2006). Experimental control of nodality via equal presentations of conditional discriminations in different equivalence protocols under speed and no-speed conditions. *Journal of the Experimental Analysis of Behavior, 85*(1), 107–124. doi:10.1901/jeab.2006.58-04

Johnston, J. M., & Pennypacker, H. S. (2009). *Strategies and tactics of behavioral research*(3rd ed.).

Kantor, J. R., & Smith, N. W. (1975). *The science of psychology: An interbehavioral survey*. Chicago, Illinois: Principia Press.

Knowledge. (2019). Oxford Dictionary.

MacKay, H. (1991). Conditional stimulus control. In I. H. Iversen & K. A. Lattal (Eds.), *Experimental analysis of behavior: Part 1*: 13th November 1991.

Margolis, Eric, & Stephen. (2019). Concepts. *The Stanford Encyclopedia of Philosophy* Retrieved from https://plato.stanford.edu/archives/sum2019/entries/concepts/

Moore, J. (2008). *Conceptual foundations of radical behaviorism*. Cornwall-on-Hudson, N.Y: Sloan Pub.

Ninness, C., Ninness, S., Rumph, M., & Lawson, D. (2018). The emergence of stimulus relations: Human and computer learning. *Perspectives on Behavior Science, 41*(1), 121–154. doi:10.1007/s40614-017-0125-6

O'Donohue, W., & Kitchener, R., F. (1999). Chapter 1: Introduction: The behaviorisms. In W. O'Donohue & R. F. Kitchener (Eds.), *Handbook of behaviorism* (pp. 1–13). San Diego, CA: Academic Press.

Pierce, W. D., & Cheney, C. D. (2013). *Behavior analysis and learning* (6th ed.). New York: Psychology Press.

Rachlin, H. (1999). Chapter 9: Teleological behaviorism. In W. T. O'Donohue & R. Kitchener (Eds.), *Handbook of behaviorism* (pp. 195–215): Academic Press.

Rachlin, H. (2013). About teleological behaviorism. *The Behavior analyst, 36*(2), 209. doi:10.1007/BF03392307

Ringen, J. (1999). Chapter 6: Radical behaviorism: B. F. Skinner's philosophy of science. In W. O'Donohue & R. Kitchener (Eds.), *Handbook of behaviorism* (pp. 159–178). San Diego, California: Academic PRess.

Saunders, R. R., & Green, G. (1999). A discrimination analysis of training-structure effects on stimulus equivalence outcomes. *Journal of the Experimental Analysis of Behavior, 72*(1), 117-137. doi:10.1901/jeab.1999.72–117

Sidman, M. (1994). *Equivalence relations and behavior: A research story*. Boston: Authors cooperative.

Sidman, M., & Tailby, W. (1982). Conditional discrimination vs. matching to sample: an expansion of the testing paradigm. *Journal of the Experimental Analysis of Behavior, 37*(1), 5–22. doi:10.1901/jeab.1982.37-5

Skinner, B. F. (1950). Are theories of learning necessary? *Psychological Review, 57*(4), 193–216. doi:10.1037/h0054367

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

Skinner, B. F. (1976). *About behaviorism*. New York: Vintage Books / Random House.

Skinner, B. F. (1981). Selection by consequences. *Science, 213*(4507), 501–504. doi:10.1126/science.7244649

Spencer, T. J., & Chase, P. N. (1996). Speed analysis of stimulus equivalence. *Journal of the Experimental Analysis of Behavior, 65*(3), 643–659.

Staddon, J. E. R. (1999). Chapter 9: Theoretical behaviorism. In W. O. Donohue & R. Kitchener (Eds.), *Handbook of behaviorism* (pp. 217–241). San Diego, CA: Academic Press.

Staddon, J. E. R. (2014). *The new behaviorism* (2nd ed.). New York: Psychology Press.

Tomanari, G. Y., Sidman, M., Rubio, A. R., & Dube, W. V. (2006). Equivalence classes with requirements for short response latencies. *Journal of the Experimental Analysis of Behavior*, *85*(3), 349–369.

Wang, T., McHugh, L. A., & Whelan, R. (2012). A test of the discrimination account in equivalence class formation. *Learning and Motivation, 43*(1-2), 8–13. doi:10.1016/j.lmot.2011.11.001

Watson, J. B. (1913). Psychology as the behaviourist views it. *Psychological Review, 20*(2), 158–177. doi:10.1037/h0074428

Zuriff, G. E. (1985). *Behaviorism: A conceptual reconstruction*. New York: Columbia University Press.

Differences of the Nodal Distance Effect in Sorting Tests after Different Matching-to-Sample Protocols

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Abstract

The nodal distance hypothesis states that emergent conditional responding decreases as the number of nodes increases. This study exposed 20 participants to a matching-to-sample (MTS) procedure with either a simultaneous or a simple-to-complex protocol to establish stimulus equivalence classes, consisting of 3 classes with 5 members each, followed by a sorting test, a post-class combined symmetry-transitivity test condition, and a sorting test to investigate the nodal distance effect. Percent correct responding, binary emergent conditional discrimination, reaction time, and sorting responses were used. The between-participant analysis shows that the nodal distance effect is greater for the simultaneous protocol during the MTS testing procedure and during a post-class combined symmetry-transitivity test. However, differential nodal distance effect during the sorting tests were not found. A within-participant analysis shows that the nodal distance effect is greater for simple-to-complex protocol during MTS training and testing procedure in the nodal distance effect during the MTS testing procedures with different protocols expect for reaction time. However, differential nodal distance effect during the sorting tests were not found. The post-class combined symmetry-transitivity test predicted sorting responses in accordance with the nodal structure better than the initial MTS tests.

Keywords: stimulus equivalence, matching-to-sample, sorting test, nodal distance, associative distance, simultaneous protocol, simple-to-complex protocol,

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Stimulus equivalence can be defined as stimulus substitution, a form of equivalence class where some relations emerge as one stimulus may substitute another stimulus in that class without direct training. Responding that are in accordance with stimulus equivalence can be studied through a matching-to-sample (MTS) procedure. An MTS procedure involves first establishing conditional discriminations by presenting a sample stimulus (Sa) and differentially reinforce behaviors that are under control of a positive comparison stimulus (Co+), and not by a negative comparison stimulus (Co-). The comparison stimuli (Cos) functions either as Co+s or Co-s, depending on which Sa is presented. In the presence of a Sa A, one can teach a participant to respond in the presence of a Co+ B through differential reinforcement. The AB relation in this context is referred to as a trained relation or a baseline relation, as the first letter (A) represents the Sa and the latter (B) represents the Co. However, after AB relations are directly trained in human participants, humans also tend to respond during non-trained BA relations without an history of direct reinforcement.

Sidman and Tailby (1982) suggested that stimulus equivalence holds the properties of *reflexivity, symmetry,* and *transitivity* as responding in accordance with new relations occurs without direct reinforcement. Reflexivity refers to emergent conditional relation as each stimulus has a relation to itself without direct training (e.g., if A, then A). Symmetry refers to emergent conditional relation after one conditional relation is established and occurs when changing the order of trained Sa and Co+ results in responding without direct training (e.g., if AB, then BA). Transitivity refers to emergent conditional relation after two conditional relations are established and occurs when responding during one stimulus in one conditional relation is related to another stimulus in the other relation without direct training (e.g., if AB and BC, then AC, or combined symmetry-transitivity CA). If a participant responds in accordance with reflexivity, symmetry, and transitivity of a particular stimulus class, then the participant is said to respond in accordance with stimulus equivalence. A common misunderstanding is that stimulus equivalence equals functional equivalence. A functional equivalence class refers to where topographically different stimuli can function as the same discriminative stimulus (SD) for a particular behavior. A stimulus equivalence class may function as a functional equivalence class, but the latter must be observed empirically.

There have been many different types of stimulus equivalence research that either describes, explains or applies the phenomena. Investigation of stimulus equivalence by structural variables (Fields & Verhave, 1987), different types of training structures (Arntzen, Grondahl, & Eilifsen, 2010; Arntzen & Hansen, 2011; Eilifsen & Arntzen, 2009), different types of protocols (Adams, Fields, & Verhave, 1993; Imam, 2006), preliminary training (Buffington, Fields, & Adams, 1997; Nartey, Arntzen, & Fields, 2015), impact of meaningful stimuli (Arntzen, 2004; Arntzen, Nartey, & Fields, 2014; Fields, Arntzen, Nartey, & Eilifsen, 2012; Nartey, Arntzen, & Fields, 2014), alternative measures of stimulus equivalence formation (Arntzen et al., 2017; Arntzen, Norbom, & Fields, 2015; Bortoloti & Rose, 2009; Dymond & Rehfeldt, 2001; Eikeseth, Rosales-Ruiz, Duarte, & Baer, 1997; Fields, Arntzen, & Moksness, 2014), transfer of function (Hayes, Kohlenber, & Hayes, 1991; Hayes, Deavny, Kohlenberg, Brownstein, & Shelby, 1987; Wulfert & Hayes, 1988), the relationship between stimulus equivalence and verbal behavior (Dugdale & Lowe, 1990; Lowe & Horne, 1996; McIlvane & Dube, 1996; Sidman, 1994; Stromer, Mackay, & Remington, 1996), and how applied studies (Brogård-Antonsen & Arntzen, 2019; Cowley, Green, & Braunling-Mcmorrow, 1992; Hausman, Borrero, Fisher, & Kahng, 2014; Steingrimsdottir, Arntzen, & Strandbakken, 2013) have used knowledge about stimulus equivalence to form responding of equivalence classes that are of high social validity (Baer, Wolf, & Risley, 1968).

The nodal distance hypothesis, also known as associative distance hypothesis (Fields & Verhave, 1987) is a hypothesis about stimulus equivalence formation. The hypothesis states that emergent conditional discrimination will decrease as the number of nodes between the stimuli increases. A node can be defined as stimuli that “links” other stimuli. For instance, if one were to train AB, BC, and CD relations directly, then the B stimulus would be a node during a transitivity relation AC. In this example, the AC transitivity relation is a 1-node relation. However, an AD relation has two nodes where B and C stimuli are both nodes for A and D stimuli. In this example, the AD transitivity relation is a 2-node relation. Several studies have investigated the nodal distance effect. Some studies have reported that emergent conditional discrimination occur less as number of nodes increases (Albright, Fields, Reeve, Reeve, & Kisamore, 2019; Fields & Watanabe-Rose, 2008), others have reported that increasing nodal number usually decreases response accuracy and speed (Arntzen & Holth, 2000; Bentall et al., 1998; Fields, Landon-Jimenez, Buffington, & Adams, 1995; Imam, 2001; Kennedy, Itkonen, & Lindquist, 1994; Kennedy, 1991; Spencer & Chase, 1996), some have investigated differences of transfer of function related to nodal number (Bortoloti & Rose, 2009; Imam, 2003), and others speculates that the nodal distance effect is related to the mediation of verbal behavior in stimulus equivalence formation (Bentall et al., 1998; Horne & Lowe, 1996). The nodal distance effect which can be defined as the empirical observation that emergent conditional discrimination decreases as nodes increases, has been observed during (a) MTS procedures as emergent conditional discrimination measured by accuracy decreases as nodes increases or that reaction time to Co+ increases as number of nodes increases, (b) transfer of function decreases as number of nodes increases, (c) post-class formation within-class preference performance for emergent conditional discrimination of lower nodal number, and (d) during sorting tests.

The nodal distance effect during MTS procedures measured by accuracy have been documented in several experiments (Arntzen & Holth, 2000; Imam, 2001; Kennedy et al., 1994; Spencer & Chase, 1996) where percentage of correct responding in accordance with emergent conditional discrimination decreases as the number of nodes increases. For instance, Experiment 1 by Imam (2001) trained 5-member 3-class stimuli: A1B1, B1C1, C1D1, and D1E1; A2B2, B2C2, C2D2, and D2E2; and A3B3, B3C3, C3D3, and D3E3 during a MTS procedure. The rest of the paper will refer to A1B1, A2B2, A3B3, and et cetera as AB (depending on the class size), likewise with all the other relations (B1C1, B2C2, B3C3, and et cetera will be referred to as BC), and will refer to total number of training or testing trials. The participants in the study needed to emit 90% or more correct during training trials to precede to the next phase, with 36 trials of AB stimuli; 18 trials of AB and 18 trials of BC; 9 trials of AB, 9 trials of BC, and 18 trials of CD; and 6 trials of AB, 6 trials of BC, 6 trials of CD, and 18 trials of DE. Later, the participants needed to repeat the previous procedure within 2 s of responding on to Co+ after the Sa was presented. Later, different types of test trials (baseline, symmetry, transitivity, and combined symmetry-transitivity trials) were presented. The results of this experiment showed that responding in accordance with emergent conditional discrimination decreases as number of nodes increases. However, during Experiment 2, the MTS procedure was set up to balance all of the different types of training trials where they were all presented equally number of times. The results show that the nodal distance effect was not observed. An extension of these results were done by Imam (2006). The study investigated the nodal distance effect as a function of three different MTS protocols: the simultaneous protocol, the simple-to-complex protocol, and the complex-to-simple protocol. The simultaneous protocol produces equal training and testing trials across different trial types. However, the simple-to-complex protocol and the complex-to-simple protocol normally produces differential presentations of training and testing trials. The author implemented an

MTS procedure with a simultaneous protocol, simple-to-complex protocol, and complex-to-simple protocol as the different types of training and testing trials were presented equal amount of times. This was achieved by adding differential test trial types during the last test where all relations are tested (mixed test) until there were equal amount of testing trials. The results show that the participants did not emit the nodal distance effect. The author concluded that the nodal distance effect may occur as a function of differential exposure for training and testing trials and not due to increasing number of nodes, which do not support the nodal distance hypothesis.

The nodal distance effect during MTS procedures measured by reaction time have been documented (Bentall et al., 1998; Fields et al., 1995; Imam, 2001) where reaction time to Co+s increases as number of nodes increases. For instance, Bentall, Jones, and Dickins (1998) trained 5-member 6-class (AB, BC, CD, DE) by using an errorless MTS training procedures. AB were trained without Co-s first and when 19/20 trials were correct, preceded to AB training with Co-s. When this was achieved with 19/20 correct trials, the BC stimuli were introduced without Co-s with same mastery criterion and later with Co-s. This was repeated until all of the baseline relations (AB, BC, CD, and DE) were trained. Later, baseline relations, symmetry relations, 1-node relations, and 2-node relations were tested. The results show that reaction time to Co+s increased as a function of nodal number, which supports the nodal distance hypothesis. However, Experiment 2 by Imam (2001) did not find reaction time to increase as a function of nodal number when the trials were balanced.

The nodal distance effect during transfer of function have been investigated (Bortoloti & Rose, 2009; Fields & Watanabe-Rose, 2008; Imam, 2003). Transfer of function is the phenomenon where by establishing another function for stimuli in a stimulus equivalence class results to generalization of that function for the entire class (e.g., when the stimulus equivalence class of stimuli A, B, and C occurs, training stimulus A as SD for clapping, then stimulus B and C may also function as a SD for clapping). For instance, Fields and Watanabe-Rose (2008) trained 6-member (AB, BC, CD, DE, and EF) 2-class stimuli during MTS procedure until the participants performed 100% correct and emergent conditional discrimination was tested. Later, C1, C2, D1, and D2 were used as SDs for a differential response for each stimulus. At last, transfer of function tested how many and which differential response occurred in presence of other stimuli in class 1 and class 2. The results show that responses trained to C generalized to A and B stimuli whereas responses trained to D stimuli were generalized to E and F stimuli which supports the nodal distance hypothesis.

The nodal distance effect during post-class formation within-class preference tests have been investigated (Albright et al., 2019; Doran & Fields, 2012; Moss-Lourenco & Fields, 2011). For instance, Albright et al. (2019) used 9-member 2-class stimuli with null stimuli (Cos that have not been trained to any stimuli) to train conditional discrimination and tested for emergent conditional discrimination during a MTS procedure where the all of these trials were presented three times in random order. The null stimuli were used to control for conditional discrimination by rejection and not by selection. Later, baseline, symmetry, 1-node, 2-node, 3-node, 4-node, and 5-node relations were tested. A within-class preference test were done where the Sa were C stimuli and A or E, A or F, A or G, A or H, A or I stimuli where Cos which were the same stimuli in that class. For instance, the Sas could be C1 and the Cos could be A1 or H1 within the same trial. If the participants selected A1, then a combined symmetry-transitivity relation of 1-node occurred and if H1 was selected then a transitivity relation of 4-nodes occurred. Based on this example, the nodal distance hypothesis would predict that the participant would in the presence of C1 select A1 more often compared to H1. At last baseline, symmetry, 1-node, 2-node, 3-node, 4-node, and 5-node relations were tested. The results of this study showed that 13 out of 16 individuals emitted the nodal distance effect (responding in accordance with the nodal distance hypothesis), that participants tend to prefer transitivity relations compared to combined symmetry-transitivity relations, and that preference of lower nodal number could have occurred but may have been influenced by a greater preference for transitivity relations compared to combined symmetry-transitivity relations. However, responding during within-class preference in accordance with the nodal distance effect may be confounded by the null stimuli.

Alternative measures (Dymond & Rehfeldt, 2001) have been used to investigate the nodal distance hypothesis. Bortoloti and de Rose (2011) suggested that prior studies that have investigated the nodal distance hypothesis used discrete measurement of emergent conditional discrimination (with reaction time as an exception) and that other measures could be used to investigate nodal distance effect, preferably by a continuous measure. Bortoloti and de Rose (2009) investigated how transfer of function decreases as the nodal number between the relation increases and its correspondence to a semantic differential test. The experiment consisted of training the following relations: AB, AC, CD, DE, EF, and FG. The stimuli were faces of different expressions as A1 consisted of four different pictures of angry faces, A2 consisted of four different neutral faces, and A3 consisted of four happy faces. All of the remaining stimuli were abstract stimuli. Later, the BG and GB relations were tested. The participant that responded in accordance with these relations were later given the semantic differential test. The semantic differential test involves presenting a stimulus and instruct the participants to rate the stimulus among several bipolar scales. One scale ranged from minimum value - 3 and maximum value + 3. An “negative” adjective was placed at its minimum value and its opposite adjective was placed at its positive value. For instance, one bipolar scale consisted of “Sad” at - 3 and the word “Happy” at + 3. Stimulus D and F was evaluated by the participants by using the semantic differential test, as the results shows that stimulus D (which had one node between the A stimulus or faces) corresponded with the facial expression of stimulus A, and more often compared to stimulus F (which had three nodes between the A stimulus). However, the experiment used a one-to-many training structure, which has been previously reported to be inept to study nodal distance as linear series structure is preferred (Imam, 2001; Sidman, 1994). Another possible confounding variable is the presence of verbal instructions, as it is still debated if stimulus equivalence formation is the same as verbal behavior, or if it is something separate. Another issue regarding measurement is whether the nodal distance effect is temporary or permanent. As issued by Fields and Moss (2007), responding in accordance with emergent conditional discrimination may reach a “ceiling effect” during a MTS test which may be a measurement issue. However, the nodal distance effect may be investigated during transfer of function tests or post-class within-class preference tests after a MTS test in order to control for such ceiling effects. (Fields et al., 1990). However, there exists other alternative measurement of emergent conditional discrimination that can examine post-class formation, such as sorting tests.

A sorting test is alternative measurement of stimulus equivalence formation, consists of presenting several stimuli in “a pile”, and instruct the participants to “put together the stimuli than belongs together next to each other”. The stimuli that are sorted together is assumed to represent a stimulus equivalence class. However, neither reflexivity, symmetry or transitivity relations are investigated in sorting tests. Several studies (Arntzen et al., 2017; Arntzen et al., 2015; Fields et al., 2014) have investigate the relationship between test scores of MTS procedures and sorting tests. Fields et al. investigated the emergence or maintenance of stimulus equivalence formation that were either participant or experimenter-defined sorting classes. The experimental conditions of the study arranged a pre-sorting condition, an MTS-training where 3-node 5-member equivalence classes in an AB, BC, CD, and DE order, and was followed by a post-sorting condition. The results of the study showed that there was a concordance between MTS test results and post-sorting results. Based on previous results, Arntzen et al. (2015) investigated whether there was a difference between MTS tests and sorting tests, and documenting both immediate or delayed stimulus equivalence formation. The results of the study show that there was a high concordance between MTS test scores and sorting scores in both immediate or delayed trials. Arntzen et al. (2017) suggested that previous study had a small number of participants, that all participant showed stimulus equivalence formation of other classes, and that such preliminary training may act as a confounding variable. The study supports previous findings, that there is a concordance with MTS test scores and sorting test scores, even when preliminary training is controlled for. The nodal distance effect during sorting tests have been observed. Arntzen et al. trained and tested 10 participants for 5-member 3-class relations during an MTS procedure. Later, a pre-sorting test was used where the participants were presented for the stimuli and were instructed to put the stimuli next to each other and draw a circle around those that "belonged together". In addition, 10 other participants were trained the baseline relations, presented the sorting test and then, exposed the participants for an MTS test condition. The results showed that three out of 16 participants who showed emergent conditional discrimination also sorted some of the stimuli in accordance with the nodal structure (A, B, C, D, and E stimuli were sorted in that order). However, few studies have investigated the relationship between sorting tests and the nodal distance effect.

This present study investigated the predictions of the nodal distance hypothesis by investigating differences of responding in accordance with emergent conditional discrimination during MTS procedures with either a simultaneous or simple-to-complex protocol, responding during sorting tests, and combined symmetry-transitivity tests as post-class formation tests. This was done for investigating three questions.

Firstly, the nodal distance effect may be caused by differential exposure for training and testing trials across different trial types. As mentioned, the simultaneous protocol would produce equal training trials. However, the simple-to-complex protocol would produce more repeated training trials on the stimuli which are first introduced, compared to the stimuli that are trained at the end. In addition, repeated exposure for the testing trials would also be different. The simultaneous protocol would produce equal exposure for testing trials across trial types, while the simple-to-complex protocol would produce more testing trials on fewer nodes and less testing trials with relations that have higher nodes. The nodal distance effect may be influenced by delayed emergence as some relations are more repeatedly tested than other trials. However, the nodal distance hypothesis would predict the nodal distance effect despite having the same or different amount of training and testing trials. Does the nodal distance effect occur despite having the same or different amount of training and testing trials?

Secondly, one interpretation of the nodal distance hypothesis is that stimuli in a stimulus equivalence class may have different degree of relatedness as this may influence sorting responses in a sorting test. If all stimuli are equal equivalent to each other, then the sorting order in the sorting test would not differ with repeated measures, across participants, or across protocols. However, if there are different degrees of equivalence, then participants who responds in accordance with the nodal distance effect during MTS test conditions may also sort the stimuli in accordance with their nodal structure. Is there a concordance between the nodal distance effect during MTS procedures and sorting in accordance with the nodal structure during sorting tests?

Thirdly, differences of the nodal distance effect during the MTS test conditions may be an artefact of the different testing protocol. Thus, a post-class combined symmetry-transitivity tests were used as a common reference to compare results from different MTS protocols and sorting tests. Is a post-class combined symmetry-transitivity test better suited to investigate the nodal distance effect than using different MTS protocols and can post-class combined symmetry-transitivity tests predict sorting in accordance with the nodal structure during sorting tests?

Method

Participants

Twenty participants ranging from age 22 to 34 years old, with an average age of 25.9, and without prior knowledge or prior history of research regarding stimulus equivalence were used in this study. All participants read, then signed an informed consent form, and were asked if they had any questions after signing the form. The participants were ensured that their participation was anonymous and that they could stop their participation at any time during the experiment. The participants were told that the experimenter could not give details about the experiment prior or during the session for each participant and that they were to read the instructions prior to each condition. All participants were debriefed after their participation and were informed about the purpose of the study. All of the participants were told that the study would last for one session, ranging from 1 to 3 hours. This study was approved by The Norwegian Center for Research Data (Norsk senter for forskningssdata).

Apparatus and Materials

An office room with 3 x 4 m in OsloMet – Oslo Metropolitan University with a cubicle of 1 x 1.5 m was used to conduct the experiment. A HP Probook 450 G4 Intel CORE i5 7th Gen computer with an MTS and a sorting program were used to give instructions, record, and present conditions for all participants. The computer screen was 38 cm wide and 26 cm high. The participants could interact with the computer by using an external computer mouse. The stimuli that were used in this study were 12 abstract and 3 meaningful stimuli, as shown in Figure 1.

Procedure

General MTS procedures. All MTS conditions (simultaneous, simple-to-complex, and equivalence test) started with presenting the instructions for the following condition. The instructions were as follows (translated to English from Norwegian):

“A stimulus will appear in the middle of the screen. Click on the stimulus by using the computer mouse. By doing so, three other stimuli will be presented. Choose one of these stimuli by using the computer mouse. If you choose the correct stimulus, then sentences as “Very good” will appear on the screen. If you choose the wrong stimulus, then sentences as “Wrong” will appear on the screen. You will see a number at the bottom of the screen that will represent how many correct responses you have emitted previously. The computer will eventually not give you feedback on which responses were correct or wrong. However, based on your previous performance, you should be able to continue solving the tasks. Try your best to solve the tasks correctly. Good luck!”

A button with the text “Start experiment” started the MTS condition. The MTS condition trial started with presenting a Sa in the middle of the screen. Clicking the Sa stimulus produced three other Co, located in three out of four corners that were randomly determined. Clicking on the experimenter defined correct stimulus resulted in sentences as “Good” and other responses produced sentences as “Wrong”. The sentences were presented on the screen and nothing else. The programmed consequences were present at the screen for 1 s and the inter-trial interval was set at 0.5 s, between after programmed consequences were terminated and the presentation of a new trial. The cursor was placed at the Sa at the beginning of all trials automatically.

Programmed consequences were given 100%, 75%, 50%, and 0% during the training phases. Programmed consequences decreased if the participant responded in accordance with a successful training block, which was defined as responding in accordance a mastery criterion of 95% or more. The same training blocks were repeated if the participants did not respond in accordance with the mastery criterion. The training phase was terminated when the last training block with 0% programmed consequence probability was achieved with a mastery criterion. The test phase did not give programmed consequences and either terminated the condition or proceeded to the next training phase when all of the test trials were executed. Reliability was ensured by using two observers of the parameters for the computer-assisted delivery of procedures and measurements of behavior. These procedures and measurements were tested repeatedly for each condition prior to the study.

The independent variable. The independent variable in this study was either the implementation of (a) the simultaneous training protocol or (b) the implementation of a simple-to-complex training protocol.

The dependent variable. The dependent variables in this study were (a) accuracy (b), emergent conditional discrimination consistent responding, (c) reaction time, (d) experimenter-defined sorting responses, and (e) nodal structure sorting responses by participants who completed all of the assigned sequence of conditions.

Accuracy was defined as correct responding divided by all possible correct responding in accordance with trained relations; symmetry relations; 1-node, 2-node, and 3-node transitivity relations; and 1-node, 2-node, and 3-node combined symmetry-transitivity relations separately during MTS test and MTS equivalence test condition and measured continuously from 0%–100%. Emergent conditional discrimination consistent responding was defined as correct responding of 95% or more out of all possible correct responding in accordance with trained relations; symmetry relations; 1-node, 2-node, and 3-node transitivity relations; and 1-node, 2-node, and 3-node combined symmetry-transitivity relations separately during MTS test and MTS equivalence test conditions and measured binary (e.g., either symmetry or not). Reaction time was defined as milliseconds from the presentation of a Sa to the selection of only Co+s during responding in accordance with trained relations; symmetry relations; 1-node, 2-node, and 3-node transitivity relations; and 1-node, 2-node, and 3-node combined symmetry-transitivity relations separately during MTS test and MTS equivalence conditions and measured continuously.

Experimenter-defined class sorting responses were defined as sorting stimuli that were marked by a circle to their respective class (e.g., class 1 would contain stimulus A1, B1, C1, D1, and E1) during a sorting test. There were 3 classes total, thus the maximum score was 3 (all 3 classes of stimuli were categorized and marked by three separate circles) and minimum score was 0 (no classes of stimuli were categorized correctly). Only circles that contained either A1, B1, C1, D1, and E1; A2, B2, C2, D2, and E2; or A3, B3, C3, D3, and E3 were considered instances of experimenter-defined sorting responses. Nodal structure sorting responses were defined as experimenter-defined class sorting responses where the stimuli were also sorted in order of the nodal structure (AB, BC, CD, and DE; or ED, DC, CB, and BA are sorted in that order in their respective class, either horizontally or vertically) during the sorting test and were measured discretely.

MTS simultaneous condition. The MTS simultaneous condition consisted of training all baseline relations and then present all test trials in a linear series training structure, concurrently. As shown in Figure 2, training consisted of the following relations: AB, BC, CD, and DE were repeated five times total and were trained in random order until the mastery criterion of 95% correct or more was achieved. Thus, the participants needed to emit a minimum of 57 out of 60 correct training trials during a training block. Each completion of a training block lead to reduction in programmed consequence probability. The training phase was terminated when the last training block with 0% programmed consequence probability was achieved with a mastery criterion of 95%. Later, the testing phase consisted of presenting all other non-trained relations within a class (e.g., BC, DA, EA, …) three times, except reflexivity relations (e.g., AA, BB, CC, …).

MTS simple-to-complex condition. The MTS simple-to-complex condition consisted of training the baseline relations, and then when available, tested for symmetry, cumulative symmetry, transitivity, and combined symmetry-transitivity relations, followed by a mixed test. As shown in Figure 2, the protocol of training and testing phases has the same training and testing structure as used by Imam (2006), and were as follows:

AB relations were trained directly and BA (symmetry) relations were tested. AB and BC were trained, and CB (symmetry) were tested. AB and BC were trained, and BA and CB (symmetry) were tested. AB and BC were trained, and AC (transitivity) were tested. AB and BC were trained, and CA (combined symmetry-transitivity) were tested. Later, AB, BC, BA, CB, AC, and CA were tested randomly (mixed test). AB, BC, and CD were trained; DC (symmetry) were tested. AB, BC, and CD were trained; BA, CB, and DC were tested (symmetry). AB, BC, and CD were trained; BD and AD (transitivity) were tested. AB, BC, and CD were trained; DB and DA (combined symmetry-transitivity) were tested. Later, AB, BC, CD, BA, CB, DC, AC, BD, AD, CA, DB, and DA were tested randomly (mixed test). AB, BC, CD, DE were trained, and ED (symmetry) were tested. AB, BC, CD, DE were trained; BA, CB, DC, and ED were tested (symmetry). AB, BC, CD, and DE were trained; CE, BE, AE (transitivity) were tested. AB, BC, CD, and DE were trained; EC, EB, EA (combined symmetry-transitivity) were tested. AB, BC, CD, DE, BA, CB, DC, ED, AC, BD, CE, AD, BE, AE, CA, DB, EC, DA, EB, and EA were tested randomly (mixed test).

The training phase consisted of several training blocks as described above and where the relations in a training block were repeated three times total, in random order until the mastery criterion of 95% was achieved. The participants needed to emit minimum nine out of nine correct training trials during the AB training block; 18 out of 18 correct trials during the AB and BC training block; 26 out of 27 correct trials during the AB, BC and CD training block; and 35 out of 36 correct trials during the AB, BC, CD, and DE training block. Each successful training block resulted in a decrease of programmed consequences. The training phase was terminated when the last training block with 0% programmed consequence probability was achieved with a mastery criterion of 95%. The testing phase consisted of several testing blocks as described above and where the non-trained relations were repeated two times total in random order, except for reflexivity relations.

Sorting test condition. The sorting condition started with presenting the following instruction on the screen (translated to English from Norwegian): “A pile of stimuli will be presented on the screen. You can click and drag the stimuli to move them. Putt together the stimuli that “belongs together” by putting them next to each other. Next, draw a circle around the stimuli by clicking and dragging on the background, and make a circle around the stimuli that you think belong together. Do this twice.”

The participants needed to press a button to start the experiment. All of the 15 stimuli were presented in one pile in the middle of the screen and where the stimuli overlapped. The pile of stimuli was presented in random order. The participants could press a button that had the text “Done” to submit their answer. Later, a new instruction was presented on the screen (translated to English from Norwegian): “Have you sorted the pictures and marked how you have sorted the pictures? You can mark the pictures by holding down left mouse button and at the same time move the cursor across the screen.”

Two other buttons appeared on the screen as the left button had “Yes” and the other had “No” written on it. Clicking the “No” button resumed the sorting task, without resetting the stimuli into one pile in the middle of the screen. Clicking the “Yes” button initiated a screenshot of the screen and a new sorting trial as the same 15 stimuli were randomly presented into a new pile with the same procedure as previous, with the exception by ending the condition by pressing the “Yes” button.

MTS equivalence test condition. The MTS equivalence test condition consisted of a testing block of the following baseline and combined symmetry-transitivity relations: AB, BC, CD, DE, CA, DB, DA, EC, EB, and EA in random order three times for the participants that were exposed for MTS either the simultaneous or simple-to-complex condition.

Experimental design. The experimental design for this study was a mixed design with between-participant and within-participant analysis. As shown in Figure 3, the experimental conditions of this experiment were (a) MTS training and testing condition with either a simultaneous protocol or a simple-to-complex protocol, (b) a first sorting test condition, (c) MTS equivalence test condition, and (d) a second sorting test condition. Half of the participants were assigned to the MTS procedure with simultaneous protocol (SEQ1) and simple-to-complex protocol (SEQ2) by flipping a coin prior to the experimental session. All of the participants were later assigned to a sorting test condition, followed by the MTS equivalence test condition, and at last to the second sorting test condition.

Data analysis. The results of the participants responding were used to perform an overall analysis, a within-participant analysis, and a between-participant analysis.

The overall analysis investigated how many training trials each protocol produced and how many percent of those training trials consisted of the baseline relation AB, BC, CD, or DE. In addition, the overall analysis investigated how many testing trials each protocol produced and how many percent of those testing trials consisted of symmetry relations; 1-node, 2-node, and 3-node transitivity relations; and 1-node, 2-node, and 3-node combined symmetry-transitivity relations.

For the within-participant analysis, accuracy and emergent conditional discrimination consistent responding were calculated based on all of the test trials, the first half of all test trials, and the second half of all test trials of each test trial type during each condition, for each individual. Reaction time was calculated based on average milliseconds from presentation of the sample stimuli to the selection of correct comparison stimuli on all of the test trials (minimum six trials), the three first trials, and the three last trials during each trial type during each condition for each individual. Experimenter-defined sorting responses and nodal structure sorting responses were calculated based on the sorting responses during the first half of a sorting test condition, and during second half of a sorting test condition separately. The nodal distance effect was measured by each participant responding separately for the within-participant analysis. The nodal distance effect measured by accuracy and emergent conditional discrimination consistent responding were defined as values that were equal or lower (at least one lower value) than the previous value during a trial type of lower number of nodes for all of the test trials, first half of all test trials, and second half of all test trials separately. For instance, if a participant had an accuracy of 100% during baseline, 75% during symmetry, 50% during 1-node transitivity relation, and 25% during 1-node combined symmetry-transitivity relation, then such scores would count as an instance of the nodal distance effect. However, if a participant had an accuracy of 100% during baseline, 75% during symmetry, 50% during 1-node transitivity relation, 25% during 1-node combined symmetry-transitivity relation, and 30% during a 2-node transitivity relation, then such scores would not count as an instance of the nodal distance effect. The nodal distance effect measured by reaction time was defined as values that were higher than the previous value during a trial type of lower number of nodes for all of the test trials, first three test trials, and last three test trials for each relation. If there was lack of responding for calculation of reaction time of some trial types, then the data was not considered as an instance of the nodal distance effect.

For the between-participant analysis, the sum of emergent conditional discrimination consistent responding was calculated based on emergent conditional consistent responding of participants which were exposed for the same sequence based on all of the testing trials, first half of all testing trials, second half of all testing trials during each relation, and each condition separately. The participants' average reaction time was calculated based on the reaction time of each participants which were exposed for the same sequence based on all of the testing trials, first three testing trials, and last three testing trials during each relation by each condition. The sum of all participants' experimenter-defined sorting responses and nodal structure sorting responses in the first trial and second trial was calculated separately for sorting test 1 and sorting test 2 for participants by participants which were exposed for the same experimental sequences. For the between-participant analysis, the nodal distance effect was defined by a decrease of the sum of emergent conditional consistent responding for participants as nodes increases or an increase of participants' average reaction time as nodes increases for participants that were exposed for same sequence of conditions, based on visual analysis.

Results

The overall analysis during the training phases shows that participants that were exposed for the MTS simultaneous training protocol needed to perform minimum 240 correct training trials (including trials with programmed consequences reduction) where all of the baseline relations (AB, BC, CD, and DE) were trained equally, each relation had 25% of total training trials. The participants that were exposed for the MTS simple-to-complex training protocol needed to perform minimum 525 correct training trials (including trials with programmed consequences reduction) where 33.71% were AB relations, 32% were BC relations, 22% were CD relations, and 11.42% were DE relations. The overall analysis during the testing phases shows that participants that were exposed for the MTS simultaneous condition were presented for 180 testing trials in total. Out of those 180 testing trials, 20% were baseline relations (BLR), 20% were symmetry relations (SYM), 15% were transitivity relations with one node (TRA1), 15% were combined symmetry-transitivity relations with one node (EQ1), 10% were transitivity relations with two nodes (TRA2), 10% were combined symmetry-transitivity relations with two nodes (EQ2), 5% were transitivity relations with three nodes (TRA3), and 5% were combined symmetry-transitivity relations with three nodes (EQ3). Participants that were exposed for the MTS simple-to-complex condition were presented for 378 testing trials in total. Out of those 378 testing trials, 14.28% were BLR, 34.92% were SYM, 14.28% were TRA1, 14.28% were EQ1, 7.93% were TRA2, 7.93% were EQ2, 3.17% were TRA3, and 3.17% were EQ3. Participants that were exposed the MTS equivalence test condition were presented for 90 testing trials total. Out of those 90 testing trials, 40% were BLR, 30% were EQ1, 20% were EQ2, and 10% were EQ3.

Between-participant analysis

Sum of emergent conditional discrimination consistent responding. As shown in Figure 4, the sum of all participants emergent conditional discrimination consistent responding across different trial types shows a greater decline as nodes increases for SEQ1 participants during the MTS simultaneous condition compared to SEQ2 participants during the MTS simple-to-complex condition based on visual analysis. The sum of all participants emergent conditional discrimination consistent responding across different trial types did not show a differential responding for SEQ1 participants and SEQ2 participants during the MTS equivalence test condition based on visual analysis.

Participants' average reaction time. As shown in Figure 5, the results of participants' average reaction time across different trial types shows that SEQ1 participants emitted a greater increase in average reaction time as nodes increases during the MTS simultaneous condition compared to SEQ2 participants during the MTS simple-to-complex condition, and that results from SEQ1 shows a greater increase in average reaction time as nodes increases compared to SEQ2 during the MTS equivalence test condition based on visual analysis.

Sum of experimenter-defined sorting responses. As shown in Figure 6, the sum of experimenter-defined sorting responses of the SEQ1 participants produced no differential outcomes compared to the SEQ2 participants during the sorting test 1 and sorting test 2 condition based on visual analysis.

Sum of nodal structure sorting responses. As shown in Figure 6, the sum of nodal structure sorting responses of the SEQ1 participants produced no differential outcomes compared to the SEQ2 participants during the sorting test 1 and sorting test 2 condition based on visual analysis.

Within-Participant Analysis

An overview of all participants sequence assignment, whether they completed the training condition, their total score in the MTS testing condition, and MTS equivalence test condition is shown in Table 1. Table 2 shows the participants experimenter-defined sorting responses while Table 3 shows the participants nodal structure sorting responses. Table 3 shows that two SEQ1 participants (17905 and 17912) and that two SEQ2 participants (17909 and 17922) emitted nodal structure sorting responses. Participant 17912 did emit nodal structure sorting responses despite not responding in accordance with stimulus equivalence.

Accuracy and nodal structure sorting responses. Within-participant results of nodal structure sorting responses can be seen in Table 3 and the nodal distance effect measured by accuracy can be seen in Table 4. The nodal distance effect measured as accuracy was observed for five out of all 20 participants, where participant 17909 and 17912 also emitted nodal structure sorting responses.

Table 4 shows that the nodal distance effect measured as accuracy was observed by two SEQ2 participants (17908 and 17917) during the first MTS test conditions, by two SEQ1 participants (17912 and 17915), and one SEQ2 participant (17909) during MTS equivalence test condition. None of the participants had a concordance between accuracy during the first

MTS test condition and nodal structure sorting responds, as two out of three participants (participant 17909 and 17912) which emitted the nodal distance effect measured by accuracy during the MTS equivalence test condition also emitted also nodal structure sorting responses.

Emergent conditional discrimination consistent responding and nodal structure sorting responses. Within-participant analysis of emergent conditional discrimination consistent responding in accordance with the nodal distance effect can be seen in Table 5. The nodal distance effect measured as emergent conditional discrimination consistent responding was observed by four out of 20 participants, where 17909 also emitted nodal structure sorting responses.

Table 5 shows that the nodal distance effect measured by emergent conditional discrimination consistent responding was observed by one SEQ1 participants (17910), two SEQ2 participants (17908 and 17917) during the first MTS test condition, and by one SEQ2 participant (17909) during MTS equivalence test condition. None of the participants had a concordance between emergent conditional discrimination consistent responding during MTS test condition and nodal structure sorting responds. One participant (17909) who emitted the nodal distance effect measured by emergent conditional discrimination consistent responding during MTS equivalence test condition also emitted the nodal structure sorting responses. As shown in Figure 7, the participant 17909 also wrote “Order 1-5” during the sorting test 1 in the second trial.

Reaction time and nodal structure sorting responses. Within-participant analysis of reaction time of responding in accordance with the nodal distance effect can be seen in Table 6. The nodal distance effect measured as reaction time was observed by five out of 20 participants, where participant 17905 also emitted nodal structure sorting responses.

Table 6 shows that the nodal distance effect measured by reaction time was not observed during the MTS test condition. The nodal distance effect measured by reaction time was observed by five SEQ1 participants (17904, 17905, 17910, 17918, 17920) during the MTS equivalence test condition.

Discussion

Whether the participants (a) responded more in accordance with the nodal distance effect as a function of different MTS protocols, (b) emitted the nodal distance effect during the MTS tests and sorted in accordance with the nodal structure during sorting tests, and (c) had an concordance between the nodal distance effect during a post-class formation test and sorted in accordance with the nodal structure depended on if the between-participant analysis or within-participant analysis were used.

Between-participant analysis of the nodal distance effect

The between participant analysis shows firstly, that the participants that were exposed for the simultaneous protocol had a higher nodal distance effect compared to the simple-to-complex protocol during the MTS test condition. Secondly, the participants that were exposed for the simultaneous protocol and the simple-to-complex protocol did not produce differential nodal structure sorting responses based on MTS test results. Thirdly, the nodal distance effect during the post-class combined symmetry-transitivity was only observed for reaction time and not emergent conditional discrimination consistent responding. These results support the nodal distance hypothesis as the nodal distance effect occurs despite having different training and testing trials. These results show no concordance between the nodal distance effect during the MTS testing condition and sorting responses which are sorted in accordance with the nodal structure. These results show that the post-class combined symmetry-transitivity test did not predict sorting responses which are sorted in accordance with the nodal compared to the nodal distance effect in the MTS simultaneous or MTS simple-to-complex test conditions.

Within-participant analysis of the nodal distance effect

The within-participant analysis measured by accuracy shows that firstly, the nodal distance effect was lower for participants which were exposed for the simultaneous protocol compared to the participants which were exposed for the simple-to-complex protocol. Only participants that were exposed for the simple-to-complex protocol responded in accordance with the nodal distance effect measured by accuracy during the MTS test condition. Secondly, those participants that emitted the nodal distance effect during the MTS test conditions did not sort in accordance with the nodal structure during sorting tests. Thirdly, those participants who emitted the nodal distance effect during the post-class combined symmetry-transitivity tests were more likely to emit sorting responses in accordance with the nodal structure compared to those participants that emitted the nodal distance effect during the MTS test with either simultaneous or simple-to-complex protocol. These results do not support the nodal distance hypothesis as the nodal distance effect may have occurred due to being exposed for different amounts of training and testing trials. These results show no concordance between the nodal distance effect during MTS test conditions with different protocols and sorting responses in accordance with the nodal structure during sorting tests. These results show that the nodal distance effect during the post-class combined symmetry-transitivity tests predicted sorting responses that are in accordance with the nodal structure better than the MTS test with either simultaneous or simple-to-complex protocol, indicating that comparing the nodal distance effects during MTS test with different protocol may not be suitable.

The within-participant analysis measured by emergent conditional discrimination consistent responding shows firstly, that the nodal distance effect for participants which were exposed for the simultaneous protocol was lower than those that were exposed for the simple-to-complex protocol in MTS test condition. Secondly, those participants that emitted the nodal distance effect during the MTS test conditions did not sort in accordance with the nodal structure during sorting tests. Thirdly, the only participant which emitted the nodal distance effect during the post-class combined symmetry-transitivity sorting test also emitted sorting responses which were in accordance with the nodal structure. These results support the nodal distance hypothesis as the nodal distance effect occurred for one participant which was exposed for the MTS simultaneous protocol. These results show no concordance between the nodal distance effect during the MTS tests and sorting in accordance with the nodal structure. These results show that the nodal distance effect during the post-class combined symmetry-transitivity tests predicted sorting responses that are in accordance with the nodal structure better than the MTS test with either simultaneous or simple-to-complex protocol, indicating that the nodal distance effect measured by the MTS test procedures may be an artefact of the procedure.

The within-participant analysis measured by reaction time shows firstly, that the nodal distance effect for participants which were exposed for the simultaneous protocol was higher than those that were exposed for the simple-to-complex protocol in MTS test condition. Secondly, those participants that emitted the nodal distance effect during the MTS test conditions did not sort in accordance with the nodal structure during sorting tests. Thirdly, one out of five participants emitted the nodal distance effect during the post-class combined symmetry-transitivity sorting test also emitted sorting responses which were in accordance with the nodal structure. These results support the nodal distance hypothesis as the nodal distance effect occurred despite having the same amount of training and same amount of testing trials across trial types. These results show no concordance between the nodal distance effect during MTS test conditions with different protocols and sorting responses in accordance with the nodal structure during sorting tests. These results show that the post-class combined symmetry-transitivity test did not predict sorting responses that are in accordance with the nodal structure. In addition, the within-participant analysis shows that the nodal distance effect measured by accuracy or emergent conditional discrimination consistent responding predicted sorting in accordance with nodal structure during sorting tests better than reaction time as a measure for the nodal distance effect.

External validity

Emergent conditional discrimination. The nodal distance effect measured by accuracy or emergent conditional discrimination consistent responding is consistent with previous findings (Bentall et al., 1998; Imam, 2001; Spencer & Chase, 1996), while not consistent with other findings (Imam, 2001, 2006). The results of this present study is consistent by the findings obtained by Spencer and Chase (1996). The authors trained the subjects similarly to the simple-to-complex protocol, although did not test for emergent conditional discrimination between training of new baseline relations, whereas the emergent conditional discrimination was documented after the training of baseline relations. The authors documented the nodal distance effect based on a within-participant analysis. This present study replicated their findings as the simple-to-complex protocol as participants also produced the nodal distance effect measured by accuracy or emergent conditional discrimination consistent responding. However, the authors' study shows that the participants emitted a greater nodal distance effect compared to the results of participants which were exposed for the MTS simple-to-complex protocol for this present study. These differences may be influenced by a higher amount of training trials or the presence of testing trials between the introduction of new baseline relations during this study. The results of this present study is consistent with Experiment 1 conducted by Imam (2001) which was a systematic replication of the findings of Spencer and Chase (1996). However, the results of this study is not consistent with the results of Experiment 2 of the study by Imam (2001). The authors study did not find the nodal distance effect when the amount of training trials and amount of testing trials were equal, while this present study documented the nodal distance effect based on a between-participant analysis, and for one participant based on a within-participant analysis, despite having equal amount of training trials and equal amount of testing trials. A possible confounding variable may be that the participants which were used in Experiment 1 were also used in Experiment 2 as preliminary training may have influenced the nodal distance effect. One interpretation may be that fewer test trials of higher node relations may enhance the nodal distance effect as this can explain why the nodal distance effect occurs more frequently during MTS test conditions based on simple-to-complex protocols. However, the overall analysis shows that the simultaneous protocol produced differential percentage of testing trials based on different number of nodes despite producing the same amount of different testing trials although these differences were less than the testing trials produced by the simple-to-complex protocol. The results of this present study is not consistent with the findings conducted by Imam (2006). The author did not find the nodal distance effect when participants were exposed for simultaneous, simple-to-complex, and complex to simple protocol. In contrast, this present study documented the nodal distance effect when participants were exposed for the simultaneous protocol based on a between-participant analysis, and one participant based on a within-participant analysis. A possible confounding variable may be where the participants during the authors study were exposed for a higher amounts of symmetry trials compared to other testing trials during the simultaneous protocol while this present study presented equal amounts of all of the testing trials. In addition, the sequence of protocols during the author's study shows that three out of four participants started with the complex-to-simple protocol where this may also have influenced the nodal distance effect. Only one participant during the authors study started with the simple-to-complex protocol and showed a greater nodal distance effect during the last "speed" condition compared to other participants.

Reaction time. The nodal distance effect measured by reaction time is consistent with previous findings (Bentall et al., 1998; Spencer & Chase, 1996), while not consistent with other findings (Imam, 2006). This present study is consistent with the findings of Bentall et al. (1998) which documented that reaction time increases as number of nodes increases. The results of the authors findings show a greater nodal distance effect measured by reaction time compared to this present study. However, the nodal distance effect measured by reaction time was not observed during the MTS test condition based on the within-participant analysis but was observed in the post-class combined symmetry-transitivity test. Further studies should investigate the nodal distance effect measured by reaction time with a larger number of nodes. This present study is not consistent with the findings by Imam (2006). The author found that the number of nodes did not change the mean speed of correct responding in accordance with different trial types, during the simultaneous protocol, simple-to-complex protocol, and complex-to-simple protocol based on a within-participant analysis. However, this present study found that reaction time to Co+ increased as number of nodes increased greater for participants that were exposed for the simultaneous protocol based on a within-participant analysis during the post-class combined symmetry-transitivity test. A possible confounding variable is that the author used the same participants during different protocols with different sets of stimuli as such preliminary training may have influenced the nodal distance effect.

Sorting responses. The nodal distance effect measured by nodal structure sorting responses during this study is consistent with previous findings (Arntzen et al., 2017). The authors found three participants that sorted all classes in accordance with the nodal structure during either the first or second sorting test. Out of those three participants, one participant did sort three out of three possible classes in accordance with the nodal structure during the first sorting test and the second sorting test. Another participant sorted three out of three possible classes in accordance with the nodal structure during the first sorting test and sorted zero out of three possible classes in accordance with the nodal structure during the second sorting test. A third participant sorted three out of three possible classes in accordance with the nodal structure during the first sorting test. This present study replicated these results as three participants sorted three out of three possible classes in accordance with the nodal structure. Out of those three participants, one participant was exposed for the simultaneous protocol, and the two remaining were exposed for the simple-to-complex protocol. However, another participant which was exposed for the simultaneous protocol did emit stable sorting of two out of three possible classes in accordance with the nodal structure during all sorting test trials. The results of this present study also show that the simultaneous protocol and the simple-to-complex protocol did not produce differential effects on experimenter-defined sorting responses. All of the participants categorized the stimuli in three different categories as most of the categorizations were in accordance with the experimenter-defined classes, except for two participants. One participant which was exposed for the simultaneous protocol sorted two classes (with the exception of one stimulus in one class) into the same circle, whereas the other participant which was exposed for the simple-to-complex protocol categorized seven different classes during the sorting test.

Post-class combined symmetry-transitivity tests. The nodal distance effect measured by post-class combined symmetry-transitivity tests during this study is consistent with the findings of previous studies (Bentall et al., 1998). The authors show that the nodal distance effect as measured by reaction time decreases when being repeatedly exposed for test trials. These findings were replicated by this present study as the nodal distance effect during the MTS testing phase was greater compared to the post-class combined symmetry-transitivity test for participants which were exposed for the simultaneous protocol based on the between-participant analysis. However, this present study extended these findings whereas sorting in accordance with nodal structure was better predicated by the nodal distance effect measured by accuracy or emergent conditional discrimination consistent responding during a post-class combined symmetry-transitivity test compared to the nodal distance effect during the simultaneous protocol or the simple-to-complex protocol based on the within-participant analysis. In addition, these results did not find a relationship between sorting in accordance with the nodal structure, neither changing the nodal distance effect measured by reaction time for the within-participant analysis.

Methodological limitations

The findings of this present study may be confounded by several variables. One possible confounding variable is that the simple-to-complex protocol produced more training and testing trials compared to the simultaneous protocol. Further studies could alter the simultaneous protocols as the training blocks are presented eight times instead of five. However, such high number of training blocks may require several sessions which may confound the results. Another possible confounding variable is where symmetry relations occurs more often during the simple-to-complex protocol than other testing trials. One can implement a simple-to-complex protocol where symmetry relations are only presented during a cumulative symmetry testing phase. A third possible confounding variable is that although different trial types were tested with equal amount of presentations during the simultaneous protocol, the percentage of testing trials with different nodes were not equal. Further studies should investigate if the nodal distance effect occurs when the percentage of testing trials with different nodes are held constant. A fourth possible confounding variable during this study is the presentation of the stimuli in sorting test as they were presented in random order. The first stimuli in a pile may have influenced the order of the sorting responses. In addition, the instructions did not specify whether to sort the stimuli in order or not during the sorting responses. Further studies should control for the order of stimuli presented in a sorting test trial and whether instructions which specifies that sorting responses should be categorized in their order effects sorting in accordance with nodal structure.

Summary

This present study investigated the nodal distance hypothesis by evaluating (a) the nodal distance effect as a function of either a MTS simultaneous protocol and a MTS simple-to-complex protocol, (b) the nodal distance effect measured by sorting in accordance with the nodal structure during sorting tests, and (c) concordance between a post-class combined symmetry-transitivity test and the nodal distance effect during MTS procedures with either a simultaneous protocol or simple-to-complex protocol or by sorting in accordance with the nodal structure; measured by accuracy, emergent conditional discrimination consistent responding, reaction time, experimenter-defined sorting responses, and by nodal structure sorting responses; and analyzed by using a between-participant analysis or a within-participant analysis.

The between-participant analysis shows that participants (a) that were exposed for the simultaneous protocol emitted a greater nodal distance effect compared to the participants exposed for the simple-to-complex protocol, (b) that sorting in accordance with nodal structure was not affected by different MTS training and testing protocols, and (c) that combined symmetry-transitivity tests did not predict sorting in accordance with nodal structure responses better than responding during MTS test conditions with either a simultaneous protocol or simple-to-complex protocol. These results support the nodal distance hypothesis.

The within-participant analysis shows that participants (a) that were exposed for the simple-to-complex protocol emitted a greater nodal distance effect compared to the participants exposed for the simultaneous protocol (with the exception for one participant when measured by accuracy or emergent conditional discrimination consistent responding, and participants when measured by reaction time), (b) that those participants who emitted the nodal distance effect during the MTS test conditions with either a simultaneous protocol or simple-to-complex protocol did not emit sorting in accordance with nodal structure, and (c) that those participants that emitted the nodal distance effect during a post-class combined symmetry-transitivity tests predicted sorting in accordance with nodal structure better compared to those participants that emitted the nodal distance effect during MTS test conditions with either a simultaneous protocol or simple-to-complex protocol. These results show that the MTS procedure with the simple-to-complex protocol enhances the nodal distance effect but also indicates that participants that were exposed for the simultaneous protocol also emitted the nodal distance effect, hence supporting the nodal distance hypothesis.

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References

Adams, B. J., Fields, L., & Verhave, T. (1993). Effects of test order on intersubject variability during equivalence class formation. *The Psychological Record, 43*(1), 133, 697–712.

Albright, L., Fields, L., Reeve, K., Reeve, S., & Kisamore, A. (2019). Relatedness of equivalence class members: Combined effects of nodality and relational type. *The Psychological Record, 69*(2), 277–289. doi:10.1007/s40732-019-00329-6

Arntzen, E. (2004). Probability of equivalence formation: Familiar stimuli and training sequence. *The Psychological Record, 54*(2), 275–291. doi:10.1007/BF03395474

Arntzen, E., Granmo, S., & Fields, L. (2017). The relation between sorting tests and matching-to-sample tests in the formation of equivalence classes. *The Psychological Record, 67*(1), 81–96. doi:10.1007/s40732-016-0209-9

Arntzen, E., Grondahl, T., & Eilifsen, C. (2010). The effects of different training structures in the establishment of conditional discriminations and subsequent performance on tests for stimulus equivalence. *The Psychological Record, 60*(3), 437–461. doi:10.1007/BF03395720

Arntzen, E., & Hansen, S. (2011). Training structures and the formation of equivalence classes. *European Journal of Behavior Analysis, 12*(2), 483–503. doi:10.1080/15021149.2011.11434397

Arntzen, E., & Holth, P. (2000). Probability of stimulus equivalence as a function of class size vs. number of classes. *The Psychological Record, 50*(1), 79–104. doi:10.1007/BF03395344

Arntzen, E., Nartey, R., & Fields, L. (2014). Identity and delay functions of meaningful stimuli: Enhanced equivalence class formation. *The Psychological Record, 64*(3), 349–360. doi:10.1007/s40732-014-0066-3

Arntzen, E., Norbom, A., & Fields, L. (2015). Sorting: An alternative measure of class formation? *The Psychological Record, 65*(4), 615–625. doi:10.1007/s40732-015-0132-5

Baer, D. M., Wolf, M. M., & Risley, T. R. (1968). Some current dimensions of applied behavior analysis. *Journal of Applied Behavior Analysis, 1*(1), 91–97. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1310980/. doi:10.1901/jaba.1968.1-91

Bentall, R., Jones, R., & Dickins, D. (1998). Errors and response latencies as a function of nodal distance in 5-member equivalence classes. *The Psychological Record, 49*(1), 93–115. doi:10.1007/BF03395309

Bortoloti, R., & De Rose, J. C. (2011). An "Orwellian" account of stimulus equivalence. are some stimuli "more equivalent" than others? *European Journal of Behavior Analysis, 12*(1), 121–134. doi:10.1080/15021149.2011.11434359

Bortoloti, R., & Rose, J. (2009). Assessment of the relatedness of equivalent stimuli through a semantic differential. *The Psychological Record, 59*(4), 563–590. doi:10.1007/BF03395682

Brogård-Antonsen, A., & Arntzen, E. (2019). Analyzing conditions for recognizing pictures of family members in a patient with Alzheimer's disease. *Behavioral Interventions, 34*(2), 293–304. doi:10.1002/bin.1655

Buffington, D., Fields, L., & Adams, B. (1997). Enhancing equivalence class formation by pretraining of other equivalence classes. *The Psychological Record, 47*(1), 69–96. doi:10.1007/BF03395213

Cowley, B. J., Green, G., & Braunling-Mcmorrow, D. (1992). Using stimulus equivalence procedures to teach name-face matching to adults with brain injuries. *Journal of Applied Behavior Analysis, 25*(2), 461–475. doi:10.1901/jaba.1992.25-461

Doran, E., & Fields, L. (2012). All stimuli are equal, but some are more equal than others: Measuring relational preferences within an equivalence class. *Journal of the Experimental Analysis of Behavior, 98*(3), 243–256. doi:10.1901/jeab.2012.98-243

Dugdale, N., & Lowe, C. F. (1990). Naming and stimulus equivalence. In D. E. Blackman & H. Lejeune (Eds.), *Behavior analysis in theory and practice: Contributions and controversies* (pp. 115–138). Hove, UK: Erlbaum.

Dymond, S., & Rehfeldt, R. A. (2001). Supplemental measures of drived stimulus relations *Experimental Analysis of Human Behavior Bulletin, 19,* 8–12.

Eikeseth, S., Rosales-Ruiz, J., Duarte, A., & Baer, D. (1997). The quick development of equivalence classes in a paper-and-pencil format through written instructions. *The Psychological Record, 47*(2), 275–284. doi:10.1007/BF03395225

Eilifsen, C., & Arntzen, E. (2009). On the role of trial types in tests for stimulus equivalence. *European Journal of Behavior Analysis, 10*(2), 187–202. doi:10.1080/15021149.2009.11434318

Fields, L., Adams, B. J., Verhave, T., & Newman, S. (1990). The effects of nodality on the formation of equivalence classes. *Journal of the Experimental Analysis of Behavior, 53*(3), 345–358. doi:10.1901/jeab.1990.53-345

Fields, L., Arntzen, E., & Moksness, M. (2014). Stimulus sorting: A quick and sensitive index of equivalence class formation. *The Psychological Record, 64*(3), 487–498. doi:10.1007/s40732-014-0034-y

Fields, L., Arntzen, E., Nartey, R., & Eilifsen, C. (2012). Effects of a meaningful, a discriminative, and a meaningless stimulus on equivalence class formation. *Journal of the Experimental Analysis of Behavior, 97*(2), 163–181. doi:10.1901/jeab.2012.97-163

Fields, L., Landon-Jimenez, D. V., Buffington, D. M., & Adams, B. J. (1995). Maintained nodal-distance effects in equivalence classes. *Journal of the Experimental Analysis of Behavior, 64*(3), 372–372.

Fields, L., & Moss, P. (2007). Stimulus relatedness in equivalence classes: Interaction of nodality and contingency. *European Journal of Behavior Analysis* 141–159. doi:10.1080/15021149.2007.11434279

Fields, L., & Verhave, T. (1987). The structure of equivalence classes. *Journal of the Experimental Analysis of Behavior, 48*(2), 317–332. doi:10.1901/jeab.1987.48-317

Fields, L., & Watanabe-Rose, M. (2008). Nodal structure and the partitioning of equivalence classes. *Journal of the Experimental Analysis of Behavior, 89*(3), 359–381. doi:10.1901/jeab.2008-89-359

Hausman, N. L., Borrero, J. C., Fisher, A., & Kahng, S. (2014). Improving accuracy of portion-size estimations through a stimulus equivalence paradigm. *Journal of applied behavior analysis,Medline, 47*(3), 485–499. doi:10.1002/jaba.139

Hayes, S., Kohlenber, B., &, & Hayes, L. (1991). The transfer of specific and general consequential functions through simple and conditional equivalence equations. *Journal of the Experimental Analysis of Behavior,* 119–137.

Hayes, S. C., Deavny, J. M., Kohlenberg, B. S., Brownstein, A. J., & Shelby, J. (1987). Stimulus equivalence and the symbolic control of behavior. *Revista Mexicana de Analisis de la Conducta, 13*(3), 361–374.

Horne, P. J., & Lowe, C. F. (1996). On the origins of naming and other symbolic behavior. *Journal of the Experimental Analysis of Behavior, 65*(1), 185–241. doi:10.1901/jeab.1996.65-185

Imam, A. A. (2001). Speed contingencies, number of stimulus presentations, and the nodality effect in equivalence class formation. *Journal of the Experimental Analysis of Behavior, 76*(3), 265–288. doi:10.1901/jeab.2001.76-265

Imam, A. A. (2003). Assesing transfer of response speed and nodality via conditional discriminations. *Journal of the Experimental Analysis of Human Behavior Bulletin, 76*, 265–288.

Imam, A. A. (2006). Experimental control of nodality via equal presentations of conditional discriminations in different equivalence protocols under speed and no-speed conditions. *Journal of the Experimental Analysis of Behavior, 85*(1), 107–124. doi:10.1901/jeab.2006.58-04

Kennedy, C., Itkonen, T., & Lindquist, K. (1994). Nodality effects during equivalence class formation: An extension to sight-word reading and concept development. *Journal of Applied Behavior Analysis, 27*(4), 673–683.

Kennedy, C. H. (1991). Equivalence class formation influenced by the number of nodes separating stimuli. *Behavioural Processes, 24*(3), 219–245. doi:10.1016/0376-6357(91)90077-D

Lowe, C. F., & Horne, P. J. (1996). Reflections on naming and other symbolic behavior. *Journal of the Experimental Analysis of Behavior, 65*(1), 315–340. doi:10.1901/jeab.1996.65-315

McIlvane, W. J., & Dube, W. V. (1996). Naming as a facilitator of discrimination. *Journal of the Experimental Analysis of Behavior, 65*(1), 267–272. doi:10.1901/jeab.1996.65-267

Moss-Lourenco, P., & Fields, L. (2011). Nodal structure and stimulus relatedness in equivalence classes: Post-class formation preference tests. *Journal of the Experimental Analysis of Behavior, 95*(3), 343–368. doi:10.1901/jeab.2011.95-343

Nartey, R., Arntzen, E., & Fields, L. (2014). Two discriminative functions of meaningful stimuli that enhance equivalence class formation. *The Psychological Record, 64*(4), 777–789. doi:10.1007/s40732-014-0072-5

Nartey, R., Arntzen, E., & Fields, L. (2015). Enhancement of equivalence class formation by pretraining discriminative functions. *Learning & Behavior, 43*(1), 20–31. doi:10.3758/s13420-014-0158-6

Sidman, M. (1994). *Equivalence relations and behavior: A research story*. Boston: Authors cooperative.

Sidman, M., & Tailby, W. (1982). Conditional discrimination vs. matching to sample: An expansion of the testing paradigm. *Journal of the Experimental Analysis of Behavior, 37*(1), 5–22. doi:10.1901/jeab.1982.37-5

Spencer, T. J., & Chase, P. N. (1996). Speed analysis of stimulus equivalence. *Journal of the Experimental Analysis of Behavior, 65*(3), 643–659.

Steingrimsdottir, H. S., Arntzen, E., & Strandbakken, L. E. (2013). The effect of using a conditional discrimination procedure to teach name-face relation to a person diagnosed with dementia. *Alzheimer's & Dementia: The Journal of the Alzheimer's Association, 9*(4), P760–P761. doi:10.1016/j.jalz.2013.05.1544

Stromer, R., Mackay, H. A., & Remington, B. (1996). Naming, the formation of stimulus classes, and applied behavior analysis. *Journal of Applied Behavior Analysis, 29*(3), 409–431. doi:10.1901/jaba.1996.29-409

Wulfert, E., & Hayes, S. C. (1988). Transfer of a conditional ordering response through conditional equivalence classes. *Journal of the Experimental Analysis of Behavior, 50*(2), 125–144.

Table 1

An Overview of MTS Conditions and Each Participants Accuracy of All Test Trials.

P#	Sequence	Training	Full MTS test	Full EQ Test
17920	SEQ1	Y	Y (100%)	Y (100%)
17907	SEQ1	Y	Y (99%)	Y (100%)
17918	SEQ1	Y	Y (97%)	Y (100%)
17904	SEQ1	Y	Y (97%)	Y (100%)
17905*	SEQ1	Y	Y (97%)	Y (100%)
17916	SEQ1	Y	Y (95%)	Y (100%)
17910	SEQ1	Y	Y (95%)	Y (98%)
17912*	SEQ1	Y	N (62%)	N (52%)
17915	SEQ1	Y	N (54%)	N (65%)
17903	SEQ1	N	-	-
17919	SEQ2	Y	Y (100%)	Y (100%)
17914	SEQ2	Y	Y (100%)	Y (100%)
17906	SEQ2	Y	Y (100%)	Y (100%)
17908	SEQ2	Y	Y (99%)	N (72%)
17913	SEQ2	Y	Y (99%)	Y (100%)
17921	SEQ2	Y	Y (99%)	Y (95%)
17922*	SEQ2	Y	Y (99%)	Y (100%)
17909*	SEQ2	Y	Y (99%)	Y (98%)
17917	SEQ2	Y	Y (98%)	Y (100%)
17911	SEQ2	N	-	-

Note. Participants (P#) sequence assignment, whether (Y) or not (Y) they completed training, accuracy of all testing trials during the testing condition of MTS simultaneous, simple-to-complex (Full MTS test) or MTS equivalence test condition (Full EQ test). The star (*) indicates participants that also emitted the nodal structure sorting responses.

Table 2

An Overview of Participants Experimenter-Defined Sorting Responses

		Sorting test 1														Sorting test 2					
P#	SEQ	First trial							Second trial							First trial			Second trial		
17920	SEQ1	**500**	**050**	**005**					**500**	**050**	**005**					**500**	**050**	**005**	**500**	**050**	**005**
17907	SEQ1	**500**	**050**	**005**					**500**	**050**	**005**					**500**	**050**	**005**	**500**	**050**	**005**
17918	SEQ1	**500**	**050**	**005**					**500**	**050**	**005**					**500**	**050**	**005**	**500**	**050**	**005**
17904	SEQ1	**500**	**050**	**005**					**500**	**050**	**005**					**500**	**050**	**005**	**500**	**050**	**005**
17905*	SEQ1	**500**	**050**	**005**					**500**	**050**	**005**					**500**	**050**	**005**	**500**	**050**	**005**
17916	SEQ1	**500**	**050**	**005**					**500**	**050**	**005**					**500**	**050**	**005**	**500**	**050**	**005**
17910	SEQ1	**500**	**050**	**005**					**500**	**050**	**005**					**500**	**050**	**005**	**500**	**050**	**005**
17912*	SEQ1	501	**050**	003					504	**050**	-					**500**	**050**	**005**	**500**	**050**	**005**
17915	SEQ1	**500**	041	014					**500**	041	014					**500**	041	014	**500**	041	014
17903	SEQ1	-	-	-					-	-	-					-	-	-	-	-	-
17919	SEQ2	**500**	**050**	**005**					**500**	**050**	**005**					**500**	**050**	**005**	**500**	**050**	**005**
17914	SEQ2	**500**	**050**	**005**					**500**	**050**	**005**					**500**	**050**	**005**	**500**	**050**	**005**
17906	SEQ2	**500**	**050**	**005**					**500**	**050**	**005**					**500**	**050**	**005**	**500**	**050**	**005**
17908	SEQ2	200	020	002	200	110	011	011	110	110	002	110	110	101	011	**500**	**050**	**005**	**500**	**050**	**005**
17913	SEQ2	**500**	**050**	**005**					**500**	**050**	**005**					**500**	**050**	**005**	**500**	**050**	**005**
17921	SEQ2	**500**	**050**	**005**					**500**	**050**	**005**					**500**	**050**	**005**	**500**	**050**	**005**
17922*	SEQ2	**500**	**050**	**005**					**500**	**050**	**005**					**500**	**050**	**005**	**500**	**050**	**005**
17909*	SEQ2	-	-	-					**500**	**050**	**005**					**500**	**050**	**005**	**500**	**050**	**005**
17917	SEQ2	**500**	**050**	**005**					**500**	**050**	**005**					**500**	**050**	**005**	**500**	**050**	**005**
17911	SEQ2	-	-	-					-	-	-					-	-	-	-	-	-

Note. This table shows participants' (P#) sequence assignment, individual performance during sorting test 1 and soring test 2, measured by the first and second trial during a sorting test. The triads of numbers represent circles containing stimuli and represents stimuli of class 1, 2, and 3, and are repeated in that order. For instance, participant 17920 sorted all of the 1, 2, and 3 class stimuli correctly and separately during the first trial of sorting test 1, marked 3 circles around them, which was notated as 500 (5 stimuli which belonged to class 1), 050 (5 stimuli which belonged to class 2), and 005 (5 stimuli which belonged to class 3). Participant 17912 made 3 circles whereas one of them contained all of the class 2 stimuli (050), one containing all of the class 1 stimuli with one additional class 3 stimulus (501), and another circle containing three class 3 stimuli (003) during the first trial of sorting test 1. Participant 17920 made three circles, while participant 17908 made seven circles during the first trial of sorting test 1. The bald font represents the presence of participants experimenter-defined sorting responses (participants that made a circle containing only all members of a class). The star symbol (*) indicates participants that also emitted the nodal structure sorting responses.

Table 3

An Overview of Participants Nodal Structure Sorting Responses

		Sorting test 1		Sorting test 2	
P#	SEQ	First trial	Second trial	First trial	Second trial
17920	SEQ1	000	000	000	000
17907	SEQ1	000	000	000	000
17918	SEQ1	000	000	000	000
17904	SEQ1	000	000	000	000
17905	SEQ1	010	110	110	110
17916	SEQ1	000	000	000	000
17910	SEQ1	000	000	000	000
17912	SEQ1	010	010	111	111
17915	SEQ1	000	000	000	000
17903	SEQ1	-	-	-	-
17919	SEQ2	000	000	000	000
17914	SEQ2	000	000	000	000
17906	SEQ2	000	000	000	000
17908	SEQ2	000	000	000	000
17913	SEQ2	000	000	000	000
17921	SEQ2	000	000	000	000
17922	SEQ2	111	000	000	111
17909	SEQ2	000	111	111	010
17917	SEQ2	000	000	000	000
17911	SEQ2	-	-	-	-

Note. This table shows participants' (P#) sequence assignment (SEQ), individual nodal structure sorting responses during sorting test 1 and soring test 2, measured by the first trial and second trial. The triads of numbers represent nodal structure sorting responses of class 1 stimuli, class 2 stimuli, and class 3 stimuli in that order. For instance, participant 17922 emitted three nodal structure sorting responses of class 1 stimuli, class 2 stimuli, and class 3 stimuli in sorting test 1 during the first trial and was noted as 111. Participant 17912 emitted one nodal structure sorting responses, specifically class 2 stimuli in sorting test 1 during the first trial and was noted as 010. Participant 17905 emitted two nodal structure sorting responses consisting of class 1 stimuli and class 2 stimuli in sorting test 1 during the second trial and was noted as 110.

Table 4.

The Nodal Distance Effect Measured by Accuracy

	P#	SEQ	BLR	SYM	TRA1	EQ1	TRA2	EQ2	TRA3	EQ3
MTS test										
AT	17908	SEQ2	100	100	100	100	100	100	100	91.6
FH	17917	SEQ2	100	100	100	100	100	100	100	66.6
	17908	SEQ2	100	100	100	100	100	100	100	83.3
SH	-	-	-	-	-	-	-	-	-	-
EQ test										
AT	17912*	SEQ1	97.2			37.0		11.1		0
	17909*	SEQ2	100			96.3		88.8		88.8
FH	17912*	SEQ1	94.4			53.8		22.2		0
SH	17912*	SEQ1	100			21.4		0		0
	17915	SEQ1	83.3			57.1		55.5		0
	17909*	SEQ2	100			92.8		88.8		80

Note. An overview of the nodal distance effect measured accuracy (as the number represents percentage correct responding), across participants (P#), types of trials (BLR represents baseline relations, SYM represents symmetry relations, TRA represents transitivity relations, EQ represents combined symmetry-transitivity relations, and the numbers represents number of nodes for that relation), conditions, based on all test trials (AT), first half of all test trials (FH), and second half of all test trials (SH) based on each relation for each condition. The EQ test represents MTS equivalence test condition. The negative symbol (-) represents that there were none participants that responded in accordance with the nodal distance effect during such measurement or conditions. The star symbol (*) indicates participants that also emitted nodal structure sorting responses in the sorting tests.

Table 5

The Nodal Distance Effect Measured by Emergent Conditional Discrimination Consistent Responding

	P#	SEQ	BLR	SYM	TRA1	EQ1	TRA2	EQ2	TRA3	EQ3
MTS test										
AT	17910	SEQ1	1	1	1	1	0	0	0	0
	17917	SEQ2	1	1	1	1	1	1	0	0
	17908	SEQ2	1	1	1	1	1	1	1	0
FH	17917	SEQ2	1	1	1	1	1	1	1	0
	17908	SEQ2	1	1	1	1	1	1	1	0
SH	-	-	-	-	-	-	-	-	-	-
EQ test										
AT	17909*	SEQ2	1			1		0		0
FH	-	-	-			-		-		-
SH	-	-	-			-		-		-

Note. An overview of the nodal distance effect measured by emergent conditional discrimination consistent responding (responding in accordance with mastery criterion of 95% or higher of that trial type), across participants (P#), types of trials (BLR represents baseline relations, SYM represents symmetry relations, TRA represents transitivity relations, EQ represents combined symmetry-transitivity relations, and the numbers represents number of nodes for that relation), conditions, based on all test trials (AT), first half of all test trials (FH), and second half of all test trials (SH) based on each relation for each condition. The EQ test represents MTS equivalence test condition. The negative symbol (-) represents that there were none participants that responded in accordance with the nodal distance effect during such measurement or conditions. The star symbol (*) indicates participants that also emitted nodal structure sorting responses in the sorting tests.

Table 6

The Nodal Distance Effect Measured by Reaction Time

	P#	SEQ	BLR	SYM	TRA1	EQ1	TRA2	EQ2	TRA3	EQ3
MTS test										
AT	-	-	-	-	-	-	-	-	-	-
FH	-	-	-	-	-	-	-	-	-	-
SH	-	-	-	-	-	-	-	-	-	-
EQ test										
AT	17920	SEQ1	1641.2			2229.4		2764.2		2764.8
	19704	SEQ1	3240.6			3935.2		4293.5		5261.3
	17905*	SEQ1	2385.6			2727		3328.5		4884.8
	17910	SEQ1	3456			3840		4224.7		7937
FH	-	-	-			-		-		-
SH	17920	SEQ1	1410.6			1767.6		2570.6		2874
	17918	SEQ1	2189			2565		3322.3		3600
	17904	SEQ1	1410.3			1589.3		4346.3		4595
	17910	SEQ1	1758.3			2232.6		3946.6		4730.6

Note. An overview of the nodal distance effect measured reaction time (average milliseconds from the presentation of sample stimuli to selection of correct comparison stimuli based on individual responding), across participants (P#), types of trials (BLR represents baseline relations, SYM represents symmetry relations, TRA represents transitivity relations, EQ represents combined symmetry-transitivity relations, and the numbers represents number of nodes for that relation), conditions, based on all test trials (AT), first three trials of all test trials (FH), and last three trials of all test trials (SH) based on each relation for each condition. The EQ test represents MTS equivalence test condition. The negative symbol (-) represents that there were none participants that responded in accordance with the nodal distance effect measurement or conditions. The star symbol (*) indicates participants that also emitted nodal structure sorting responses in the sorting tests.

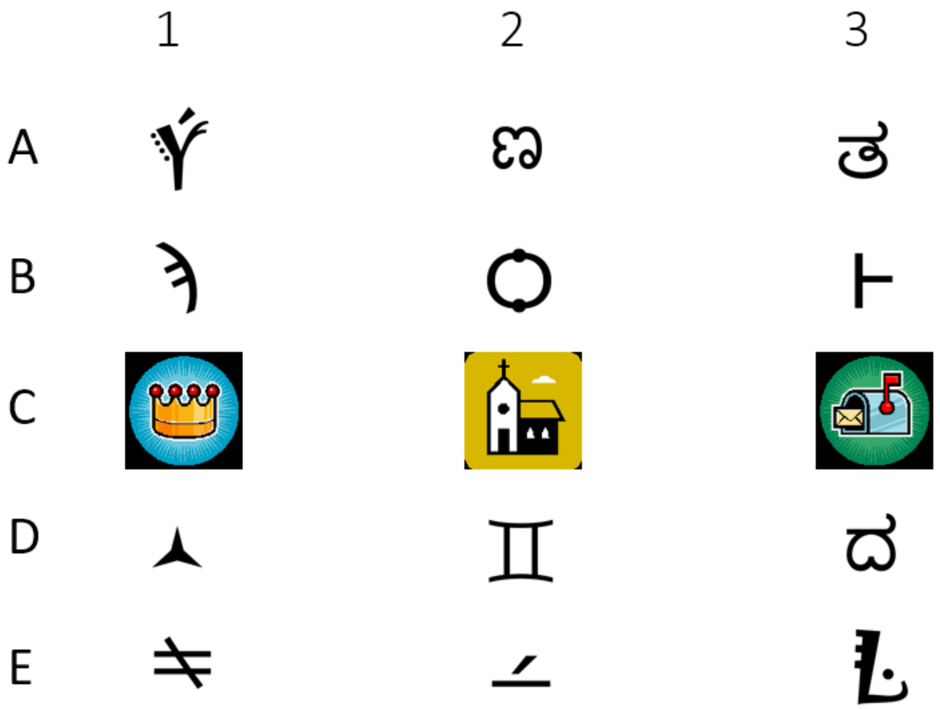

Figure 1. An overview of the stimuli that were used during the study. The stimuli membership was indicated by the letters A, B, C, D, and E, and the stimulus class categorization is indicated by the numbers 1, 2, and 3.

MTS Simultaneous Condition																				
	BLR				SYM				TRA						EQ					
	0-n				0-n				1-n			2-n		3-n	1-n			2-n		3-n
	AB	BC	CD	DE	BA	CB	DC	ED	AC	BD	CE	AD	BE	AE	CA	DB	EC	DA	EB	EA
Train	60	60	60	60																
Test*	69	69	69	69	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9

MTS Simple-to-Complex Condition																				
	BLR				SYM				TRA						EQ					
	0-n				0-n				1-n			2-n		3-n	1-n			2-n		3-n
	AB	BC	CD	DE	BA	CB	DC	ED	AC	BD	CE	AD	BE	AE	CA	DB	EC	DA	EB	EA
Train	36																			
Test					6															
Train	72	36																		
Test						6														
Train	108	72																		
Test					12	12														
Train	144	108																		
Test									6											
Train	180	144																		
Test															6					
Test*	186	150			18	18			12						12					
Train	222	186	36																	
Test							6													
Train	258	222	72																	
Test					24	24	12													
Train	294	258	108																	
Test										6		6								
Train	330	294	144																	
Test																6		6		
Test*	336	300	150		30	30	18		18	12		12			18	12		12		
Train	372	336	186	36																
Test								6												
Train	408	372	222	72																
Test					36	36	24	12												
Train	444	408	258	108																
Test											6		6	6						
Train	480	444	294	144																
Test																	6		6	6
Test*	486	450	300	150	42	42	30	18	24	18	12	18	12	12	24	18	12	18	12	12

Figure 2. A cumulative overview of training and testing phases by MTS conditions starting from top to bottom. The name of each condition is indicated above. The left side represents whether the phases were training or testing phases and the top side represents which trial type the participants were exposed for (BLR represents baseline, SYM is symmetry, TRA is transitivity, and EQ is combined symmetry-transitivity). "X-n" represents the number of nodes and the letters represents which sample or comparison stimuli were presented. The number represents total training trials when programmed consequences are reduced and the total amount of testing trials in each phase. The star symbol (*) represents mixed trials.

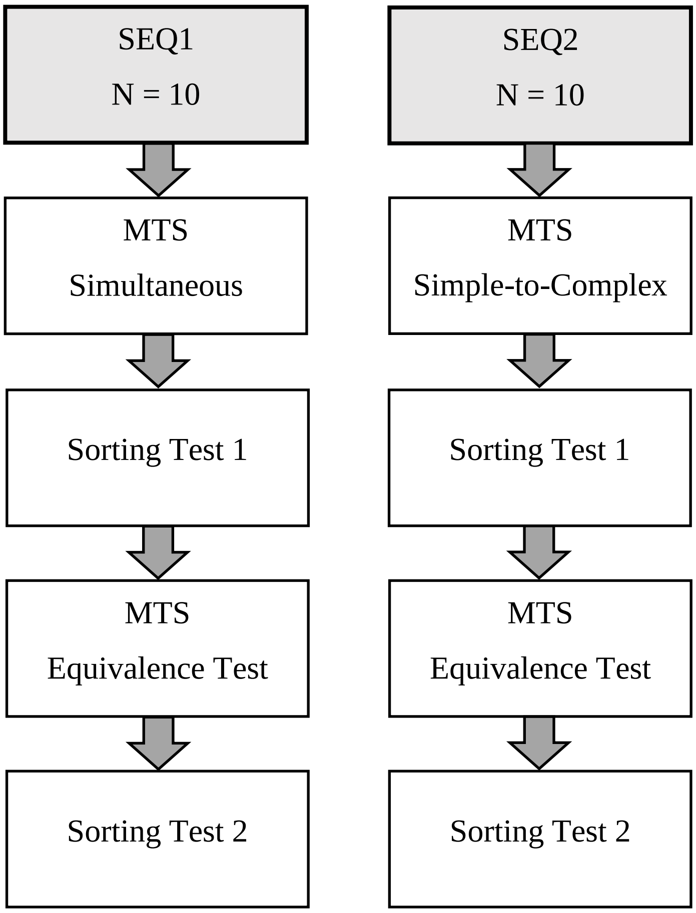

Figure 3. An overview of participants and which sequences of conditions they were exposed for, beginning from the top and ending at the bottom.

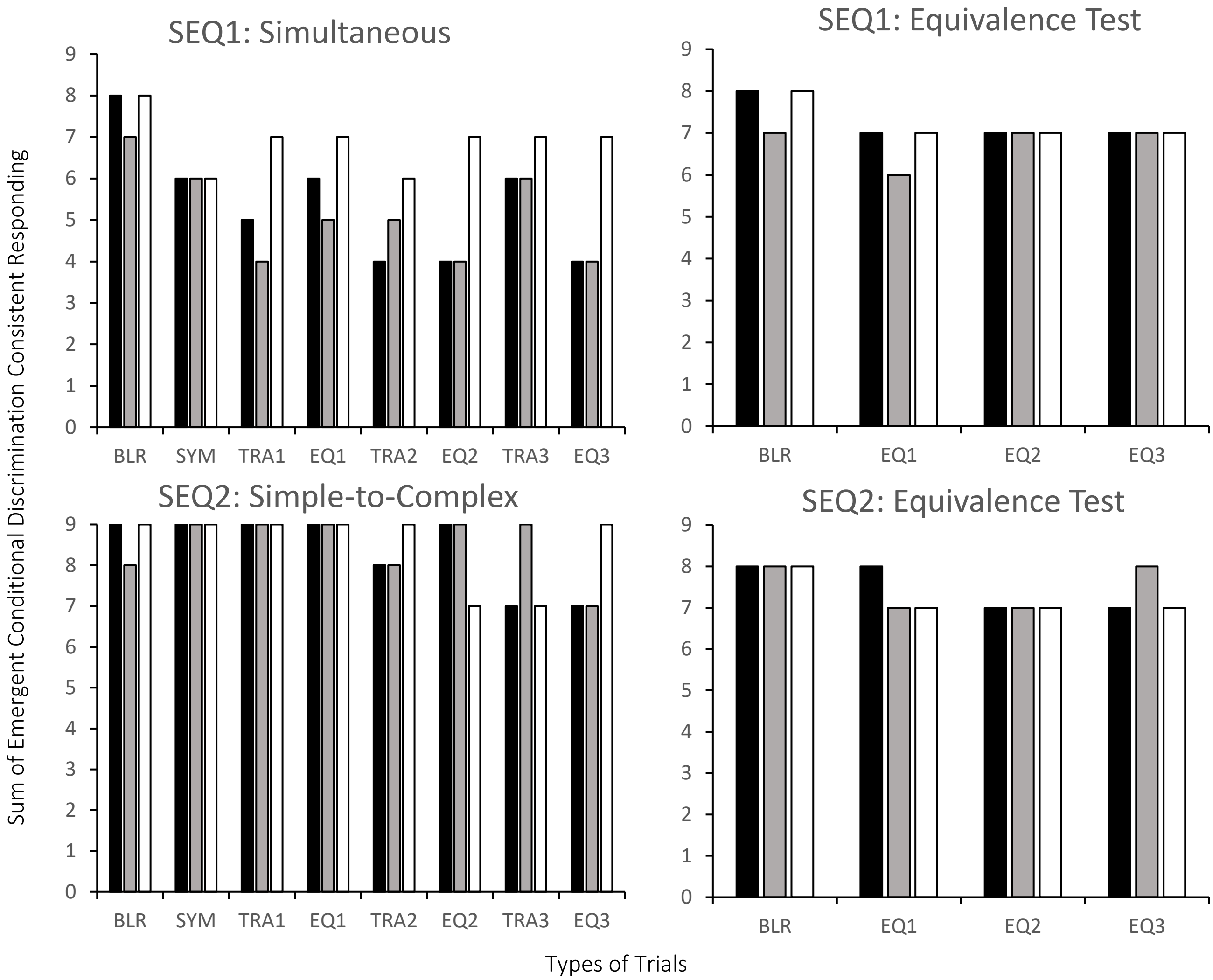

Figure 4. A visual representation of the sum of emergent conditional discrimination consistent responding of participants which were exposed for the same experimental sequences. The black, grey and white represents sum of emergent conditional discrimination consistent responding of participants based on all of the test trials, first half of all test trials, and second half of all test trials by each relation, in that order. The titles above the graphs indicate the conditions, Y-axis represents sum of emergent conditional discrimination consistent responding, and the X-axis represents different test trial types.

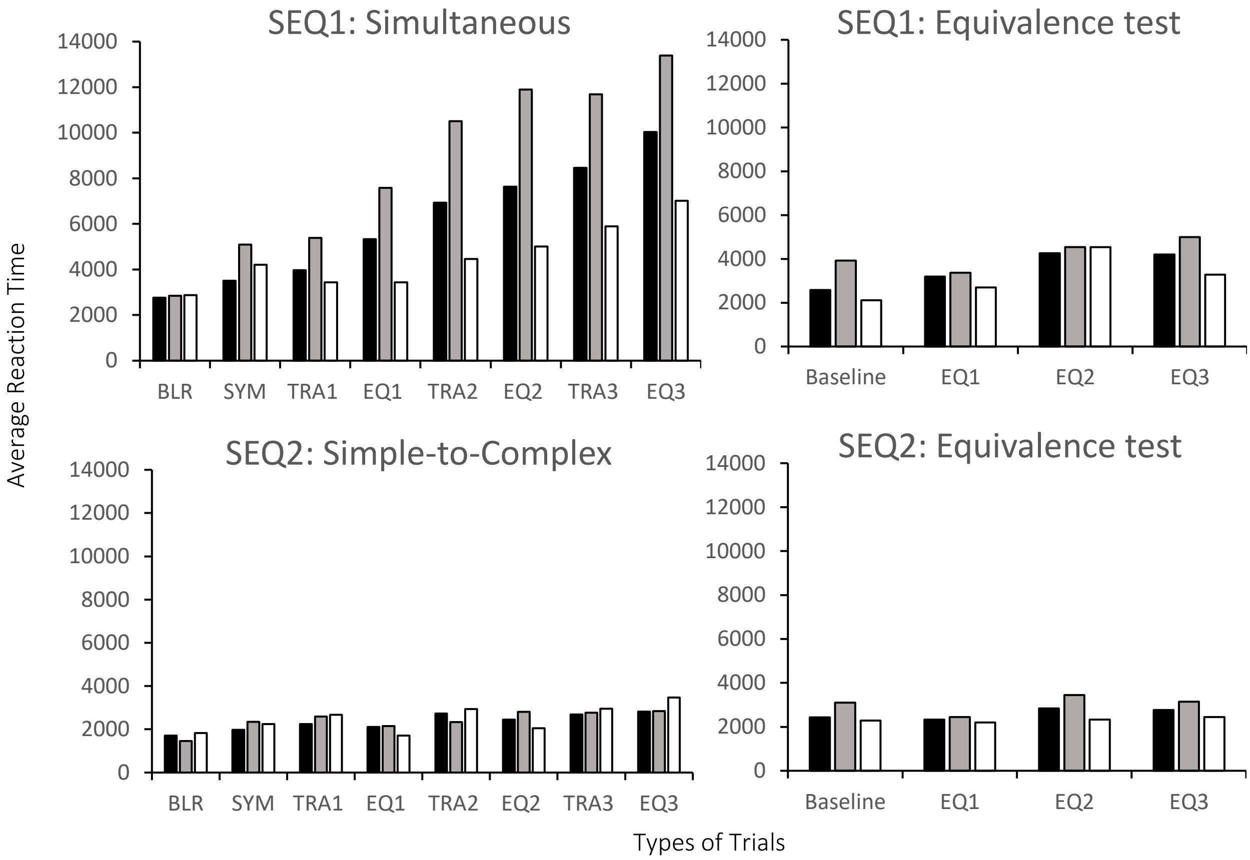

Figure 5. A graphical representation of average reaction time based on all participants' individual reaction times, and types of trials during MTS testing phases and the MTS equivalence test condition. The black, grey, and white bars represent average reaction time based on all of the test trials (minimum six trials), first three trials of all test trials, and last three trials of all test trials for each relation, in that order. The title of each graph indicates each condition, Y-axis represents all participants' average reaction time in milliseconds from presentation of the sample stimuli to the selection of correct comparison sitimuli and the X-axis represents different trial types.

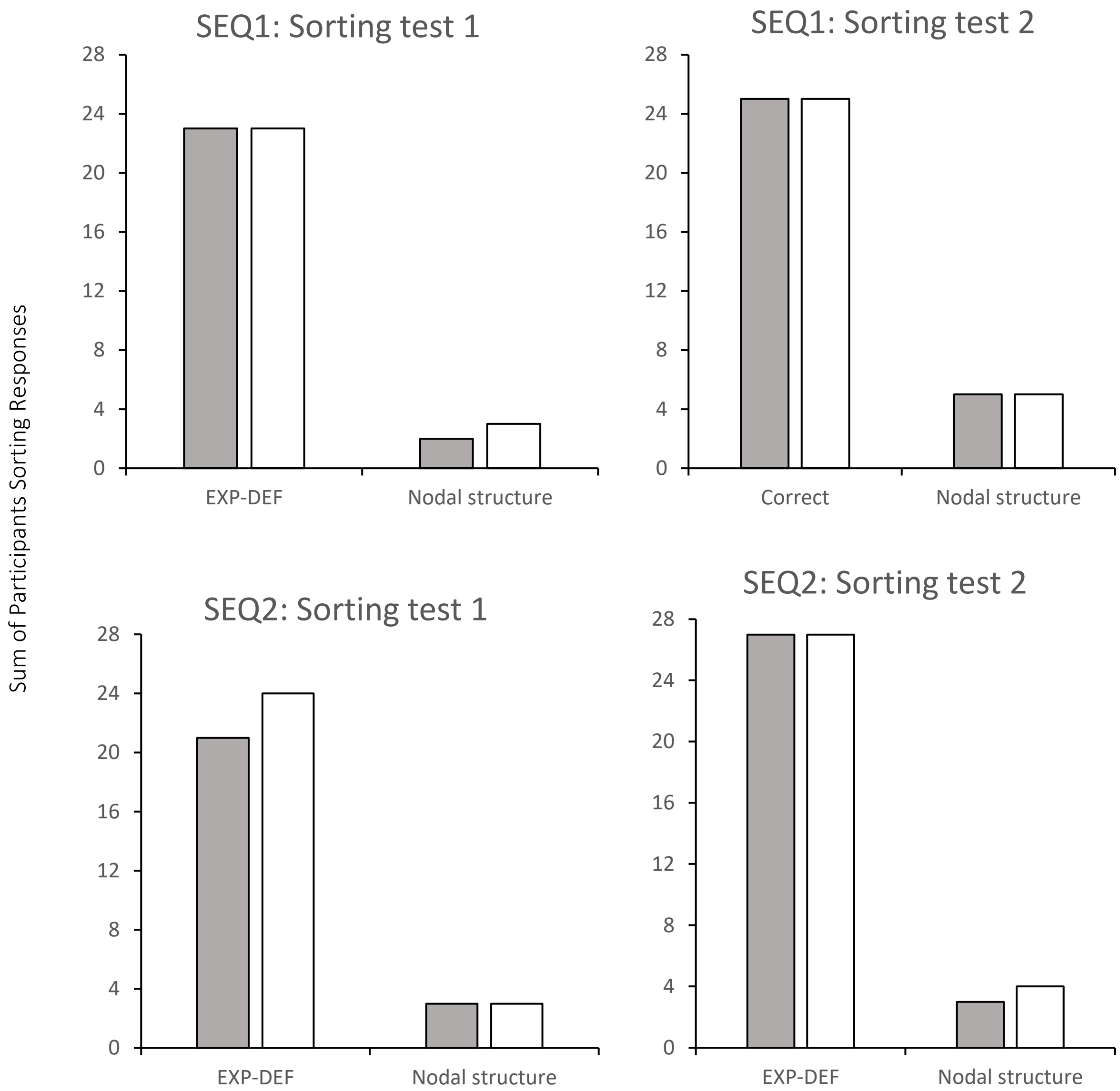

Figure 6. A graphical representation of the sum of experimenter-defined sorting responses (EXP-DEF) and nodal structure sorting responses based on all participants which were exposed for the same experimental sequences, during sorting test 1 condition and sorting test 2 condition for SEQ1 and SEQ2 participants. The grey and white bars represent sum of participants sorting responses, during the first trials and the second trials of a sorting test in that order. The title of each graph indicates each condition, Y-axis represents the sum of all participants' responses and the X axis represents experimenter-defined sorting responses or nodal structure sorting responses.

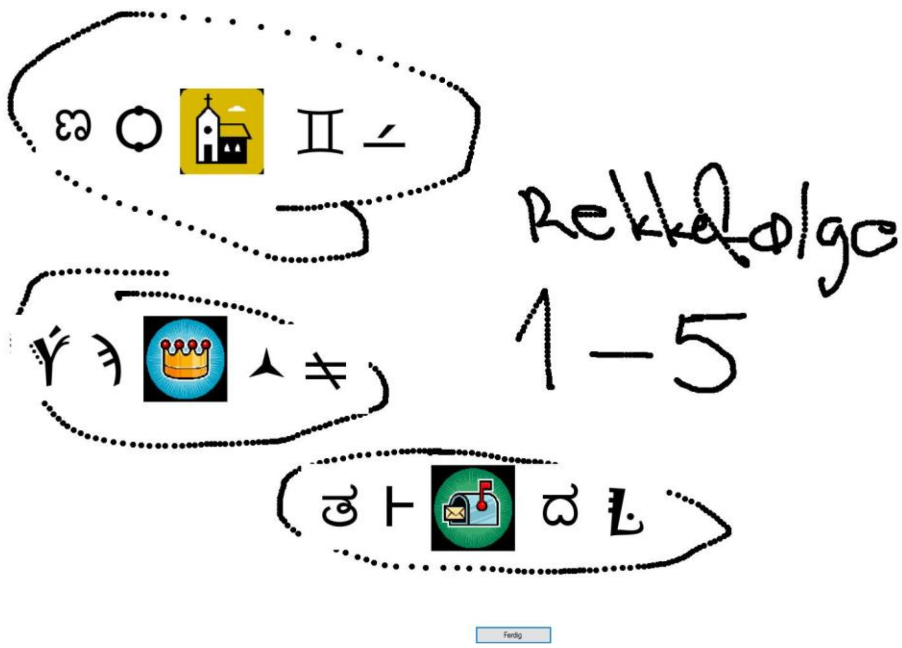

Figure 7. A screenshot of participant SEQ2 17909 nodal structure sorting responses during sorting test 1 in the second trial. The writing shows “Rekkefølge 1-5” (“Order 1-5” translated from Norwegian to English).

Reflections of ethical standards and privacy

Institutions regarding higher education are required by law to conduct research that are of ethical standards and that protects the participants that are taking part of such research.
In Norway, The National Research Ethical Committee (Den nasjonale forskningsetiske komite or NESH) is a professional independent and advisory organ for the purpose of ensuring that research ethical guidelines are regulated and maintained by high ethical standards. Some of these guidelines includes that research which involves participants are entitled to the participant's dignity, and respect for their privacy. Such research has a responsibility to inform the participants, ensuring the participants that their contributions are voluntary, and that data obtained by the research are confidential. These, and many more, considerations were put forth in this study.

The Norwegian Center for Research Data (Norsk senter for forskningsdata or NSD) is a national archive and center for research data, as their purpose is to ensure open and easy access to research data, and by deliver services that enables research activity. This study was evaluated by NSD to be in accordance with law of privacy at as long as it is conducted in concordance with the form which was sent the 19.08.2019 to NSD (reference number: 523454) which processed data which was categorized as "general privacy".
The data that was collected during this study was (a) age of participants, (b) their gender, (c) their performance during the computer task, and (d) their verbal descriptions of what they did during the computer task after the study. Data was anonymized by establishing a randomized id-number to each participant and by rough categorization of such data. The Regional Committee for Medical and Health Professional Research Ethics (Regionale komiteer for medisinsk og helsefaglig forskninsetikk or REK) is an agency associated with the department of education, which its purpose is to (a) give advice to researchers regarding research ethical questions, (b) prevents dishonesty in research, and (c) works for the maintaining research

quality. Research that includes medical and health professional research, the collection of biological data, and exceptions of confidentiality are obligated to send an application to REK. An application to REK was not sent because this study did not perform any of these measures.

A risk and value assessment (Risikovurdering og verdivurdering) were also used to investigate the confidentiality of the data during the study. The value assessment is based on three criteria: confidentiality, integrity, and availably. Confidentiality refers to the absence of availability of data by unauthorized individuals. Integrity refers to the absence of changing data by unauthorized individuals. Availability refers to the availability to conduct research in a matter that is practical by authorized individuals. A risk assessment evaluates the degree of confidentiality, integrity, availability, and quality. This study was evaluated to have a low risk for failure of confidentiality, integrity and availability based on the risk and value assessment form (ROS analyse skjema) by OsloMet – Oslo Metropolitan University.

NSD NORSK SENTER FOR FORSKNINGSDATA

NSD sin vurdering
Prosjekttittel
Sorting tester og forskjellige protokoller
Referansenummer 523454
Registrert 04.04.2019 av Nikola Ljusic - s233920@stud.hioa.no
Behandlingsansvarlig institusjon OsloMet - storbyuniversitetet / Fakultet for helsevitenskap / Institutt for atferdsvitenskap
Prosjektansvarlig (vitenskapelig ansatt/veileder eller stipendiat) Erik Arntzen, erik.arntzen@equivalence.net, tlf: 90128261
Type prosjekt Studentprosjekt, masterstudium
Kontaktinformasjon, student Nikola Ljusic, nikola@ljusic.com, tlf: 92845529
Prosjektperiode 08.04.2019 - 30.09.2019
Status 23.10.2019 – Avsluttet
Vurdering (2)

19.08.2019 – Vurdert
NSD har vurdert endringen registrert 06.08.2019.
Det er vår vurdering at behandlingen av personopplysninger i prosjektet vil være i samsvar med personvernlovgivningen så fremt den gjennomføres i tråd med det som er dokumentert i meldeskjemaet med vedlegg den 19.08.2019. Behandlingen kan fortsette.
Prosjektet vil behandle alminnelige kategorier av personopplysninger frem til 30.09.2019
OPPFØLGING AV PROSJEKTET
NSD vil følge opp ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet.
Lykke til med prosjektet!
Kontaktperson hos NSD: Kajsa Amundsen
Tlf. Personverntjenester: 55 58 21 17 (tast 1)
11.04.2019 - Vurdert
Det er vår vurdering at behandlingen av personopplysninger i prosjektet vil være i samsvar med personvernlovgivningen så fremt den gjennomføres i tråd med det som er dokumentert i meldeskjemaet med vedlegg den 11.04.2019, samt i meldingsdialogen mellom innmelder og NSD. Behandlingen kan starte.
MELD ENDRINGER
Dersom behandlingen av personopplysninger endrer seg, kan det være nødvendig å melde dette til NSD ved å oppdatere meldeskjemaet. På våre nettsider informerer vi om hvilke endringer som må meldes. Vent på svar før endringer gjennomføres.
TYPE OPPLYSNINGER OG VARIGHET
Prosjektet vil behandle alminnelige kategorier av personopplysninger frem til 01.09.2019
LOVLIG GRUNNLAG
Prosjektet vil innhente samtykke fra de registrerte til behandlingen av personopplysninger. Vår vurdering er at prosjektet legger opp til et samtykke i samsvar med kravene i art. 4 og 7, ved at det er en frivillig, spesifikk, informert og utvetydig bekreftelse som kan dokumenteres, og som den registrerte kan trekke tilbake. Lovlig grunnlag for behandlingen vil dermed være den registrertes samtykke, jf. personvernforordningen art. 6 nr. 1 bokstav a.
PERSONVERNPRINSIPPER
NSD vurderer at den planlagte behandlingen av personopplysninger vil følge prinsippene i personvernforordningen om:
- lovlighet, rettferdighet og åpenhet (art. 5.1 a), ved at de registrerte får tilfredsstillende informasjon om og samtykker til behandlingen
- formålsbegrensning (art. 5.1 b), ved at personopplysninger samles inn for spesifikke, uttrykkelig angitte og berettigede formål, og ikke behandles til nye, uforenlige formål
-dataminimering (art. 5.1 c), ved at det kun behandles opplysninger som er adekvate, relevante ognødvendige for formålet med prosjektet
-lagringsbegrensning (art. 5.1 e), ved at personopplysningene ikke lagres lengre enn nødvendig for åoppfylle formålet
DE REGISTRERTES RETTIGHETER
Så lenge de registrerte kan identifiseres i datamaterialet vil de ha følgende rettigheter: åpenhet (art. 12), informasjon (art. 13), innsyn (art. 15), retting (art. 16), sletting (art. 17), begrensning (art. 18), underretning (art. 19), dataportabilitet (art. 20).
NSD vurderer at informasjonen om behandlingen som de registrerte vil motta oppfyller lovens krav til form og innhold, jf. art. 12.1 og art. 13.
Vi minner om at hvis en registrert tar kontakt om sine rettigheter, har behandlingsansvarlig institusjon plikt til å svare innen en måned.
FØLG DIN INSTITUSJONS RETNINGSLINJER
NSD legger til grunn at behandlingen oppfyller kravene i personvernforordningen om riktighet (art. 5.1 d), integritet og konfidensialitet (art. 5.1. f) og sikkerhet (art. 32).
For å forsikre dere om at kravene oppfylles, må dere følge interne retningslinjer og/eller rådføre dere med behandlingsansvarlig institusjon.
OPPFØLGING AV PROSJEKTET
NSD vil følge opp ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet.
Lykke til med prosjektet!
Kontaktperson hos NSD: Kajsa Amundsen
Tlf. Personverntjenester: 55 58 21 17 (tast 1)

RISIKO- OG SÅRBARHETSANALYSE FOR FORSKNINGSPROSJEKT VED OSLOMET

Fyll ut arkene 1) Risikovurdering og 2) Oppsummering_Prioritering.
Se på arkfanen "Veileder" for ytterligere informasjon.

Forskningsprosjekt - tittel:	Stimulusekvivalens
Prosjektleder:	Erik Arntzen
Prosjektnr NSD (hvis aktuelt):	523454
Prosjektnr REK (hvis aktuelt)	
Prosjektnr i UBW (Agresso) (hvis aktuelt):	
Prosjektets formål (kort beskri	Studien skal teste forskjellige protokoller (Imam, 2006) og se hvordan de viser seg i en sorting test (Arntzen et al, 2005) eller matching-to-sample
Antall registrerte informanter :	20
informanter (f.eks. studenter, medlemmer i et medlemsregister, pasienter)	Alle mellom 18-80 år uten kjennskap til stimulusekvivalens
Beskriv hvordan eventuelle koblingsnøkler lagres:	En liste av tilfeldig nummer ble laget.
Antall prosjektmedarbeidere i forskningsprosjektet?	2

Dokumentet skal lagres i arkivsystemet P360. Slik gjør du det:
1) Trykk på 360° øverst på høyre side i menylinja, etter at du har fylt ut skjemaet.
2) Logg på P360.
3) Trykk: Lagre som nytt dokument i P360. Det åpnes et vindu/sak i P360. Velg "Notat uten oppfølging".
4) Fyll ut saksnummer som gjeld ditt fakultet/sentra og tittel på dokumentet. (Se egen bruksanvisning).
5) Trykk "Fullfør".

<u>Saksnr i P360:</u>
HV: 18/12622
LUI: 18/10490
SAM: 18/11207
SPS: 18/11221
SVA: 18/11208
TKD: 18/09703

Nr.	Kategorier	Underkategorier	Hendelse	Beskrivelse/verdivurdering	Risikoelement	Eksisterende tiltak	Risikonivå S	Risikonivå K	Risikonivå Risiko	Nye tiltak
	Vurder kun hendelser og risikoelement som er reelle og relevante for dette prosjektet. Bruk nedtrekksmeny (drop down). Du kan velge samme kategori på flere linjer.	Benytt nedtrekksmeny (drop down).	**Hva kan skje?**	**Hva er den uønskede hendelsen? Hvilke tap oppstår? Hvilken betydning for prosjektet?**	**Brudd på KIT (K = Konfidensialitet, I = Integritet, T = Tilgjengelighet).** Se på arkfanen "Veileder" for ytterligere informasjon. *Fyll ut kolonnene til høyre, om eksisterende tiltak, risikonivå og nye tiltak, basert på de*	**Hva kan hindre det i å skje? Hvordan kan det oppdages?** Spesifiser allerede eksisterende tiltak.	**Sannsynlighet og konsekvens på en skala fra 1 til 4. 1 = Lav/liten, 4 = Svært høy.** Risiko generes automatisk som resultat av sannsynlighet og konsekvens.			**Beskriv forslag til nye tiltak.** De kan deles opp i organisatoriske, menneskelige og teknologiske sikringstiltak.
EKSEMPEL	***Datainnsamling***	***Lydopptak***	*Mister diktafon på vei fra informant til kontoret.*	*Uvedkommende får tilgang på opplysninger om informanter. Alle intervjudata som er lagret på diktafon mistes. Betydning for prosjektet avhenger av hvor mye informasjon som er lagret på diktafonen.*	**Konfidensialitet** *(At informasjon ikke blir kjent for uvedkommende)*	*informasjon fra diktafon til annen lagringsenhet etter hvert intervju.*	*2*	*3*	*5*	*Kryptere diktafon. Vurdere å bruke mobilapp.*
					Integritet *(At informasjon ikke blir endret utilsiktet eller av uvedkommende)*	*[Tekst]*			*0*	*[Tekst]*
					Tilgjengelighet *(At informasjon er tilgjengelig ved behov)*	*Samme som for konfidensialitet.*	*3*	*4*	*7*	*Gjøre nytt intervju*
1	**Datainnsamling**	**Notater**	Laben kan være ulåst og safen kan være ulåst	Informert samtykkeskjema kan bli stjelt, der dato og navn står på de.	Konfidensialitet		1	2	3	laben pleier å være låst og safen låser seg automatisk når den lukkes.
					Integritet	[Tekst]	0	0	0	[Tekst]
					Tilgjengelighet		0	0	0	[Tekst]
2	**Datainnsamling**	**Andre**	Data om responser, kjønn og alder er lagret på en minnepinne	Disse dataene kan bli borte eller stjelt.	Konfidensialitet		2	1	3	kategorisert etter tilfeldig generert id-nummer, slik at de ikke kan spores tilbake til deltakerene. Det er ikke noe behov for nye tiltak.
					Integritet	[Tekst]			0	[Tekst]
					Tilgjengelighet	At informerte			0	[Tekst]

Oppsummering/tiltaksplan på grunnlag av risikovurderingen:

I risikovurderingen (forrige ark), beskrev du ulike hendelser, risikonivåer og eksisterende samt nye tiltak knyttet til disse.

I denne oppsummeringen/tiltaksplanen ønsker vi at du beskriver nærmere hvordan du har <u>prioritert</u> de valgene du har gjort knyttet til å behandle data i prosjektet.

Skriv gjerne <u>kort</u> om hvilke vurderinger du har gjort for tiltakene du har valgt, og hvilke risikoreduserende tiltak som skal gjennomføres i den forbindelse.

Jeg har prioritert å behandle data ved å låse inn sammtykke skjema i safen og låse labdøren. Det er lite sannsynelig at disse kan bli stjelt. I tillegg så har kun data som er anonyme blitt lagret på en minnepinne, der disse også er anonymisert. Det kreves ikke flere tiltak.