Meaningful Stimuli and the Enhancement of Equivalence Class Formation

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Abstract

After the direct training of baseline conditional relations, the emergence of derived relations that have the properties of reflexivity, symmetry and transitivity documents the formation of equivalence classes. Studies on the formation of these equivalence classes have shown that the probability of class formation is influenced by a wide array of variables. The meaningfulness of the stimuli used has been found to be one of such important variables. The formation of equivalence classes that include meaningless or abstract stimuli only has been found to be less probable. However, the inclusion of a meaningful stimulus, such as a familiar picture in a set of other meaningless stimuli can help to convert that set of stimuli into an equivalence class. In five studies with college students, this thesis has explored the properties of meaningful stimuli that account for the class enhancement they produce. Study 1 explored how a simple discriminative function acquired by an abstract stimulus through simultaneous and/or successive discrimination training enhanced the formation of an equivalence class of which that stimulus was a member. In two experiments, Study 2 investigated how the order of training, familiar pictures, and abstract stimuli that acquired discriminative functions influenced equivalence class formation. In yet another two experiments, Study 3 studied the effect of the use of a meaningful stimulus as a class member on equivalence class formation. Two parallel groups were trained to form three 3-node 5-member equivalence classes (A→B→C→D→E) under the simultaneous protocol in both experiments. The baseline relations AB, BC, CD, and DE were trained in a serialized manner in Experiment 1 while Experiment 2 involved the concurrent training of baseline relations. Study 4 investigated whether the acquisition of an identity conditional discriminative function by a meaningless stimulus using simultaneous or delayed matching procedures would influence the likelihood of formation of an equivalence class of which it is a member along with other meaningless stimuli. In a replication to Study 4, Study 5 investigated how equivalence class formation was enhanced by the inclusion of one abstract stimulus that had acquired an identity or arbitrary conditional discriminative function on a simultaneous or delayed basis, prior to the establishment of the classes. In addition to their traditional connotative and denotative properties, these studies extend our knowledge on the class enhancing properties of meaningful stimuli to include acquired discriminative functions and delayed relational (identity and arbitrary) functions. The studies also strengthen existing findings that the inclusion of a meaningful stimulus in a set of other meaningless class enhances the formation of equivalence classes. However, its inclusion alone is shown to be insufficient to generate the class enhancement and that, the order of introduction in the serial training of the baseline relations for a class, the structural location of the meaningful stimulus in the training structure as well as its behavioral functions interact with the meaningful stimulus to account for their class enhancement. Finally, there was a strong concordance between two trial formats: matching to sample trials during class formation and sorting during post class formation sorting test in terms of participants' performances indicative of equivalence class formation.

Keywords: stimulus equivalence, meaningful stimuli, acquired discriminative functions, identity relations, arbitrary relations, serialized, concurrent, card sorting.

Sammendrag

Etter betingede diskriminasjonstrening hvor to betingede diskriminasjoner har en felles stimulus, vil en positiv test for egenskapene refleksivitet, symmetri og transitivitet demonstrere at en ekvivalensklasse er dannet. Forskning på hvordan slike stimulusklasser kan oppstå har vist at en rekke variabler påvirker sannsynligheten for at ekvivalensklasser skal oppstå. En viktig variabel som påvirker sannsynligheten for dannelsen av ekvivalensklasser er hvorvidt stimuli som inngår i klassen er meningsfulle eller ikke. Stimulussett med meningsfulle stimuli gir høy sannsynlighet for dannelse av ekvivalensklasser, mens abstrakte stimuli eller meningsløse stimuli gir lavere sannsynlighet for at ekvivalensklasser skal oppstå. Dersom en meningsfull stimulus inkluderes i et stimulussett med meningsløse stimuli, vil dette øke sannsynligheten for at ekvivalensklasser oppstår. En meningsfull stimulus kan i denne sammenheng for eksempel være et kjent bilde. I fem studier med universitetsstudenter som deltakere undersøker denne avhandlingen hvilke egenskaper ved meningsfulle stimuli som kan forklare en høyere sannsynlighet for respondering i henhold til ekvivalens. Studie 1 viste at pretrening som involverte simultan eller suksessiv diskriminasjonstrening, med én stimulus i et abstrakt stimulussett, økte sannsynligheten for respondering i henhold til stimulusekvivalens. Studie 2 undersøkte i to eksperiment hvordan rekkefølge av trening, familiære bilder og abstrakte stimuli med ervervede diskriminative funksjoner påvirket dannelse av ekvivalensklasser. Studie 3, også med to eksperimenter, undersøkte hvordan inkludering av en meningsfull stimulus i abstrakte stimulussett påvirket dannelse av ekvivalensklasser. Deltakerne i to parallelle grupper ble trent til å danne tre klasser med fem medlemmer (A→B→C→D→E) og tre noder i en simultan protokoll i begge eksperimentene. Baselinerelasjonene AB, BC, CD og DE ble gradvis introdusert i Eksperiment 1, mens alle de trente betingede diskriminasjonene ble presentert fra første treningsblokk i Eksperiment 2. Studie 4 undersøkte hvorvidt etablering av betinget diskriminativ funksjon, identitetsmatching, ved en meningsløs stimulus gjennom simultan eller *delayed* matching-to-sample prosedyrer ville påvirke sannsynligheten for dannelse av ekvivalensklasser med for øvrig meningsløse stimuli. Studie 5 var en systematisk replikasjon av Studie 4 og undersøkte hvorvidt inkludering av en abstrakt stimulus med ervervet identitet eller abstrakt betinget diskriminativ funksjon, gjennom henholdsvis simultan eller delayed matching før trening av baseline betingede diskriminasjoner påvirket dannelse av ekvivalensklasser. I tillegg til den tradisjonelle distinksjonen mellom konnotativ og denotativ betydning, supplerer studiene eksisterende empiri som viser at det å inkludere en meningsfull stimulus i et sett med for øvrig meningsløse stimuli styrker sannsynligheten for respondering i henhold til ekvivalens. Inkludering av meningsfulle stimuli alene, viste seg imidlertid å være utilstrekkelig for at ekvivalensklasser skal oppstå. Interaksjonseffekter mellom den meningsfulle stimulusen og a) rekkefølgen de betingede diskriminasjonene ble introdusert i, b) strukturell lokalisering i klassen, så vel som c) dens atferdsfunksjoner ble funnet. Avslutningsvis fant vi en sterk overenstemmelse mellom to avhengige mål; prestasjon på matching-to-sample test for derivert respondering og prestasjon på post-test sorteringsoppgave.

Nøkkelord: stimulusekvivalens, meningsfulle stimuli, ervervet diskriminativ funksjon, identitetsrelasjoner, arbitrære relasjoner, gradvis og samtidig introduksjon av betingede diskriminasjoner, sorteringstest

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Introduction

Understanding complex human behavior such as how organisms come to treat dissimilar events, particularly events that have never been related directly as if they are the same has been an interesting question for many philosophers and psychologists for many years. Researchers have investigated these and other complex phenomena under broad areas such as categorization, concept formation and symbolic functioning. Early researchers used paired-associates methods in their attempts to determine how humans might come to demonstrate this phenomenon they labeled *stimulus equivalence* (Green & Saunders, 1998).

Research on stimulus equivalence declined after the demise of the paired-associates methodology, and was only revived in the 1970s through the works of Murray Sidman[1] and his colleagues and has since been a very important research area in the field of experimental behavior analysis. Their works represented a paradigm shift from the paired–associates realm to the study of the properties of reflexivity, symmetry, and transitivity through conditional discrimination training. Stimulus equivalence research has evolved and has since been conducted with different organisms (nonhumans and humans), autistic children, adults, children, amongst others, and with stimuli of different modalities (familiar pictures, abstract stimuli, tactile, etc.).

Sidman (1994) rightly sums up the reasons for his interest and indulgence in stimulus equivalence research in this quote:

> ....one of the most fascinating observations is that when we often
> react to words and other symbols as if they *are* the things or events

[1] Murray Sidman is credited with the publication of influential papers from 1971 that sparked the interest in research in stimulus equivalence.

> they refer to. Even though we do treat word and referent as equal in all respects, we attribute some of the same properties to both. This treatment of linguistic forms as equivalent to their referents permits us to listen and read with comprehension, to work out problems in their absence, to instruct others by means of speech or text, to plan a head, to store information for use in the future, and to think abstractly - all of these by means of words that are spoken, written, or thought in the absence of the things and events they refer to (Sidman, 1994, p. 3).

This obviously has tremendous practical implications as seen in instances such as when military coup d'état makers in Ghana disfigured the statue of the overthrown president, Dr. Kwame Nkrumah in 1966. It is because both Dr. Kwame Nkrumah and his statue mean the same thing for them. Akin to this phenomenon, if after a conditional discrimination training, a participant responded in accord with equivalence by correctly substituting one stimulus for another, it is because the members of the experimentally defined classes have come to mean the same thing for the participant. Besides the emergence of the new untrained relations, and the contributions to the understanding of complex human behaviors such as problem solving and language formation, stimulus equivalence research has huge implications on the arrangement of effective conditional discrimination procedures in behavioral programs. The rest of this introduction will attempt brief descriptions of the different terms in stimulus equivalence and meaningfulness and also give some highlights on some methodological and conceptual issues in stimulus equivalence research that will be encountered in the different studies presented in this thesis document. First of all, let us discuss some concepts that will help us understand stimulus equivalence when it is introduced later in this introduction.

Stimulus control

Why do we emit certain responses in some circumstances but not in others? For example, why does a driver apply his breaks when he sees a red light on a traffic signal but not when he sees a green light? These questions imply that human behaviors as well as that of some other animals do not occur in a vacuum. These are the sort of questions that will be answered when we understand the term *stimulus control*.

When some events always precede behavior and influence its occurrence, such events are referred to as *controlling stimuli*. This is because such stimuli make it more likely or less likely for a behavior to occur in its presence. When a behavior is more likely to occur in the presence of a controlling stimulus, such stimulus is referred to as a *discriminative stimulus* (S^D or S+), while it is called an *S-delta* or *extinction stimulus* (S^Δ or S-) when a behavior is less likely to occur in its presence. Using the traffic light analogy, the red light will be an S^D for applying the brakes, whiles the green light will be an S^Δ for applying the brakes.

Discriminations vary in their complexity and in the types of environmental events they comprise. It could be a simple discrimination or conditional discrimination.

Simple discrimination. Stimulus control is established through discrimination training, which involves the explicit reinforcement of the target behaviors and the non-reinforcement or punishment of inappropriate behavior in the presence of some stimuli. Sidman (1986) used the term, *three-term contingency* ($S^D : R – S^R$) to represent what he describes as the fundamental unit of stimulus control. Discrimination that is established under the three-term contingency, where a response is reinforced in the presence of a specific stimulus is called *simple discrimination*. The response class that is produced is called a *discriminated operant* (Catania, 2007). In simple discriminations, the discriminative functions of either the S^D or S^Δ do not depend on the presence of other stimuli. An example of simple discrimination training will be an instance during teaching oral naming in a child with autism where, in the presence of a spoon (S1), the vocal response "spoon" (Rl) is reinforced and "fork" (R2) is not; and in the presence of a fork (S2), the response "fork" (R2) is reinforced and "spoon" (Rl) is not (Green, 2001)

Conditional discrimination. There can be more complex discrimination such as when the three-term contingency is brought under the control of another stimulus. Any such stimulus that comes to control the three term contingency is referred to as a *conditioned stimulus* (S^C). Thus, a new stimulus will have to set the tone or to activate the existing three-term contingency. It then becomes a *four-term contingency* represented as S^C: (S^D: R- S^R). The kind of discrimination that happens under this arrangement is *conditional discrimination*. Therefore, conditional discriminations are established by reinforcing responses to particular antecedent stimuli "if and only if" they are preceded or accompanied by particular additional stimuli. Here, each antecedent stimulus is discriminative for reinforcement or not, depending on the presence of another particular antecedent. For instance, after one hears the spoken word "spoon" (S3), picking spoon (S1) is reinforced, whereas picking fork (S2) is not, or, after hearing "fork", picking fork (S2) is reinforced, whereas picking spoon (S1) is not.

Discrimination training

Training humans or other animals to make different responses to different stimuli or different context is the goal of discrimination training. It involves the reinforcement of appropriate responses in a certain context, and the non-reinforcement of inappropriate responses in that same context. Most of the training has been done with the arrangement of contingencies in a matching-to-sample format (MTS). Usually, MTS trials begin with the presentation of a conditional stimulus which is designated as *sample*, to which the experimental subject or the learner is to respond to. Responses could be in different forms ranging from touching the stimulus to pressing a key on the computer. This is then followed by the presentation of an array of two or more other stimuli called the *comparison* or *choice* stimuli for the learner to respond to one of them. In each trial, one comparison is designated correct, and thus becomes S+ for reinforcement. In other words, responses to it are reinforced whereas responses to the other comparisons in the presence of that sample are not reinforced (S-). After a brief inter-trial interval, a new trial is presented in the same way as the first. From one trial to the other, the sample stimulus as well as the position of the S+ comparison stimulus varies unsystematically (Green, 2001).

MTS could either be *identity matching* or *arbitrary matching* or preferably *conditional discrimination* (Sidman, 2009) with the former representing when samples and their designated correct comparisons have perceptual identical characteristics, and the latter has no similarities between them. The presentation of sample and comparison stimuli could be done in different ways to warrant terms such as *Simultaneous matching* or *Delayed matching-to-sample* (DMTS). Simultaneous matching refers to the condition where the sample stimulus remains available to the subject throughout each trial until a response is made. Thus, both sample and comparisons are presented at the same time. In DMTS, the sample is removed following the onset of the comparison stimuli, for a response to be made.

Stimuli used in discrimination training could be pictorial, abstract, words, tones, and in many other forms. Relations trained could be identity (when sample and comparison are the same) or arbitrary (when sample and comparison has no obvious physical resemblance).

Particularly in stimulus equivalence research, it is crucial equivalence relations develop as a result of the manipulated variables in the experiment rather than extraneous factors such as the stimuli used. Research has therefore been usually done with sets of stimuli with which the participants have had no previous experience with. This is why stimulus equivalence research has commonly used different Cyrillic letters, Greek letters, nonsense words and syllables and other abstract shapes. For experimental control, some experimenters have conducted pretests of participants' entry performances with the stimuli to be used in the experiment.

Some of these terms and procedures will be revisited later in this thesis document. For now, I believe we have dealt with the basics that will make discussions of stimulus classes and stimulus equivalence at this stage safer.

Stimulus classes

For an individual to have the capacity to do *symbolic representation* (the use of symbols to represent or refer to events in their absence), one needs to be able to form stimulus classes. When that happens, we talk of the individual having acquired *meaning* of the concept. When two or more stimuli control a common response, those stimuli are said to be members of a stimulus class (Skinner, 1938). Different types of stimulus classes can be formed; some based on stimulus similarity whiles others are non-similarity based. These have been broadly discussed in the literature under *perceptual classes* (Fields & Reeve, 2000) and *functional stimulus classes* (Sidman, 1994).

A perceptual class refers to a class of stimuli that control a common response because of a shared common physical feature among the members of the class. Perceptual classes have therefore been referred to as *feature classes* (Mcllvane, Dube, Green, & Serna, 1993). Fields and Reeve (2000) extended the discussion and identified *dimensional classes*, *fuzzy classes*, and *polymorphous classes* as the different categories of perceptual classes that could be formed based on some physical or psychometrical dimensions of class members. Whichever form or category a perceptual class is, they are all products of primary stimulus generalization. Thus, they control the same response only because class members share some common physical characteristics.

Functional stimulus classes on the other hand, refer to classes of stimuli that do not share common physical characteristics among members but control the same response. Primary stimulus generalization, therefore, cannot be responsible for the development of functional stimulus classes. When stimuli become members of a stimulus class even without shared physical characteristics, it may be that they serve a similar behavioral function. For instance, they could all be discriminative stimuli for a common response, just as pedestrians crossing at the zebra crossing, a red traffic light and a raised arm of a traffic warden will all be discriminative for a driver to apply his brakes. Therefore, the major difference between perceptual classes and functional classes is that, primary stimulus generalization which accounts for the development of perceptual classes is not enough to account for the development of functional classes.

Some classes of stimuli may also develop when we relate stimuli that have never been related directly to one another. For instance, after teaching a child to relate the word "dog" to the picture of the dog, and then to relate the picture of the dog to the printed word DOG, the child is likely to relate the word "dog" to the printed word DOG though he had not been explicitly taught to do so. The child could now be said to have formed an equivalence class with the word "dog", the picture of a dog, and the printed word DOG as members and could replace any of the members with one another without altering the probability of a particular response occurring. Stimulus equivalence therefore is synonymous with stimulus substitutability (Green & Saunders, 1998). Besides the fact that members of a stimulus equivalence class can be substituted for one another, the relations between the members of the class should share the defining properties of *reflexivity*, *symmetry* and *transitivity* (Sidman & Tailby, 1982).

Following the discussion of the different stimulus classes, it is important to state that, members of a class should not only control the same response, but that, the response must also be less likely to occur in the presence of other stimuli that are not members of that class (Fields & Reeve, 2000). This is the essence of concepts that Keller and Schoenfeld (1950) describe as "the generalization within classes and discrimination between classes" (p.155). Concept formation, thus, occurs when people learn to classify different objects as members of a single category (Donahoe & Palmer, 1994).

Stimulus equivalence defined

Stimulus equivalence is novel conditional discriminations within arbitrary matching procedures that show directly taught conditional relations among stimuli to have the properties of *reflexivity*, *symmetry*, and *transitivity* (Sidman & Tailby, 1982). According to Sidman and Tailby (1982), these three properties borrowed from the mathematical set theory are the defining relations of equivalence relations.

Using the typical matching-to-sample procedure, a child who speaks only English can be taught to relate the English word "Pig" to the French word for pig, "porc", and then further taught to relate French word porc to the Norwegian word for pig, "gris". After these conditional relations are established, further tests could demonstrate that the relations are not just conditional, but are also equivalent.

For the conditional relations, **R** to be said to be reflexive, each stimulus must bear a relation to itself; pig**R**pig (if pig, then pig), porc**R**porc (if porc, then porc) and gris**R**gris (if gris, then gris). Correct responses to such relations without explicit reinforcement demonstrate that the child is showing *generalized identity matching* (Sidman, 1992; Sidman & Tailby, 1982).

Symmetrical relations require the conditional relations to bear bi-directionality between them; if pig**R**porc, then porc**R**pig and if porc**R**gris, then gris**R**porc. Thus, without any further training or programmed reinforcements there should be an emergence of performance where sample and comparison are interchangeable in function, such that samples come to function effectively as comparisons with former comparisons as samples. *Functional sample-comparison reversibility* (Lazar, 1977; Sidman et al., 1982) therefore constitutes tests for symmetry.

Transitive relations involve the novel combination of stimuli related through shared class membership. Thus, if after the two conditional relations pig**R**porc and porc**R**gris are explicitly taught, the relation pig**R**gris emerges without further instructions, then the relations are said to be transitive (Sidman & Tailby, 1982).

Symmetry and transitivity can be evaluated simultaneously in what is termed as a combined test for symmetry and transitivity (Catania, 2007; Sidman & Tailby, 1982) or global equivalence test (Sidman, 1986). For instance, after the establishment of the conditional relations pig**R**porc, and porc**R**gris, the emergence of gris**R**pig without explicit training would require the existence of both symmetry and transitivity between the conditions. At this point, all of the stimuli, in this case pig, porc and gris are said to be members of the same equivalence class for the child and can be interchanged for one another without altering the consequence of a response occurring.

Theoretical explanations for equivalence

Research into complex human behavior in the form of the emergence of derived responses such as equivalence and symbolic functioning has engaged different groups of theorists. Notable among these different theories are *relational frame theory* (RFT) (S. C. Hayes, Barnes-Holmes, & Roche, 2001), *naming theory* (Horne & Lowe, 1996), and *Sidman's account of equivalence* (Sidman, 1994; Sidman & Tailby, 1982).

Relational frame theory (RFT). S. C. Hayes et al. (2001) summarized the key features of what they refer to as an account of human language and cognition as follows:

> Relational Frame Theory is a behavior analytic approach to human language and cognition. RFT treats relational responding as a generalized operant, and thus appeals to a history of multiple-exemplar training. Specific types of relational responding, termed relational frames, are defined in terms of the three properties of mutual and combinatorial entailment, and the transformation of functions. Relational frames are arbitrarily applicable, but are typically not necessarily arbitrarily applied in the natural language context (S. C. Hayes et al., 2001, p. 141).

According to the proponents, RFT is about responding to relations between stimuli, and not about responding to a single stimulus. These relations termed as *frames* could either be arbitrary or non-arbitrary. RFT treats relational responding as a generalized operant, and thus appeals to a history of multiple-exemplar training. Thus, they include classes of responses that have the same effects in a given context. The forms of individual responses vary significantly and these relational frames can be organized into several families of specific types of relations, namely: *coordination*, *distinction*, *opposition*, *comparison*, *temporal*, *spatial*, *hierarchical*, *causality*, and *deictic*.

These relational frames are defined by three key properties, namely: *mutual entailment*, *combinatorial entailment*, and *transformation of function*. Mutual entailment of a relational frame implies its fundamental bi-directionality under different forms of contextual control that can include arbitrary contextual cues. In a given context, if stimulus A is related in a characteristic way to B, mutual entailment will imply that B will be related in another characteristic way to A. For instance, if A comes before B, then B comes after A will mean they are mutually connected.

Combinatorial entailment refers to instances in which two or more relations that have acquired the property of mutual entailment mutually combine. If A is related to B, and B is related to C, then the derived relations between A and C, as well as that between C and A are cases of combinatorial entailment. Thus, if A is bigger than B, and B is bigger than C, then a bigger-than relation is entailed between A and C, and a smaller-than relation is entailed between C and A. It is to be noted that mutual entailment and combinatorial entailment are the generic terms for what are called symmetry and transitivity and global equivalence respectively in stimulus equivalence as proposed by Sidman.

When the functions of one stimulus in a relational network are altered based on the functions of another stimulus in the network and the derived relation between them, transformation of function is said to have occurred. Thus, while mutual and combinatorial entailments are regulated by contextual cues, the transformation of stimulus functions are regulated by additional contextual cues.

The importance of contextual cues in relational responding makes it possible to arbitrarily relate stimuli since arbitrarily applicable responding is based on contextual cues and not just the physical characteristics of the stimuli.

In summary, a relational frame is thought of as a three-term contingency, where responding to B for instance, given A and to A given B is considered as a single response unit controlled by a relevant contextual cue following its previous correlation with differential reinforcement. The contextual cue here is the third term, the relational response of responding to B given A and A given B is the second term, and the history of differential reinforcement correlated with the contextual cue, the first term. It is by virtue of this that the relational frame as an analytic unit is considered a generalized operant, hence the term *overarching operant class* (S. C. Hayes et al., 2001). Thus, for novel behavior such as equivalence to emerge, a history of differential reinforcement and multiple-exemplar training are required.

Naming theory. This is a behavior-analytic account of the development of the *naming relation* that the proponents believe is responsible for the formation of all equivalence classes and symbolic behavior. Horne and Lowe (1996) postulate that the naming relation is a synthesis of a learning history of echoic, tacting, and listener behaviors towards certain stimuli. An echoic behavior is the reproduction or the imitation of the verbal responses of others. One's echoic behavior is a vocal response under the control of the corresponding auditory stimulus such as what happens when a class says exactly the same thing after a teacher. A child who is taught to imitate another for some time will eventually respond as listener to his or her own verbal utterances and thus will become a speaker-listener within the same skin. Vocal behavior recedes to covert level and may have automatic conditioned reinforcing properties (Skinner, 1957).

In the echoic behavior, one's speaker/listener behavior is initiated by others. However, for naming to develop, one needs more than just that. Objects will have to develop functional control over behavior. Tacting occurs when a response of a given form is evoked by a particular object or event. For instance a child who sees a shoe and says "shoe" and then gets praised has been reinforced for tacting shoe. Skinner (1957) describes the tact as the most important verbal operant. Tacting is also maintained by generalised conditioned reinforcers.

When Objects become discriminative for tacting and listener behavior, thus, when a bidirectional relation between objects and the speaker-listener behavior that they occasion are established, naming is said to have occurred. Horne and Lowe (1996) suggest that naming, once fully developed, functions as a higher order bidirectional relation and that "naming is stimulus-classifying behavior''. Thus, training in only one element of the relations can result in the whole relations being demonstrated - emergent or "free" learning. In other words, occasional reinforcement of some of the elements of the higher order relation is sufficient to maintain the entire relation. Also, after so many exemplars in which listener, echoic, and tacting behaviors are reinforced, a child will only have to hear one say the name of a novel object a few times for the name relation to emerge.

To sum up their account, Lowe and Horne (1996) describes naming as the basic unit of verbal behavior and that, it is the explanation for symbolic functioning and emergent responding. Thus, emergent repertoires are the result of stimuli being in the same name relation and successful equivalence test performances are a demonstration of bidirectional naming. Horne and Lowe's naming hypothesis as pointed out by Stromer, Mackay, and Remington (1996) defend their propositions with the following questions, namely: (a) Will nonhuman organisms fail tests of stimulus equivalence? (b) Will humans who lack the prerequisite naming skills (naming relations) fail tests of stimulus equivalence? (c) Will teaching participants to name relations that involve the stimuli used in matching-to-sample procedures influence subsequent performance on equivalence tests? They answer all of these in the affirmative and thereby support their account for equivalence.

Sidman's account of equivalence. Sidman argues that equivalence relations emerge as a direct outcome of reinforcement contingencies which produce at least two types of outcome: analytic units and equivalence relations (Sidman, 1994, 2000). According to his account, the emergence of untaught equivalence relations is a fundamental behavioral function or process which can be viewed at the same level as reinforcement, discrimination, and generalization. Thus, equivalence is behavioral given and not derivable from more primitive behavioral processes. Hence Sidman (1994) postulates that, after the conditional discrimination training, equivalence relations should emerge immediately. Any failure to generate equivalent relations after conditional discrimination training is attributable to procedural anomalies which are independent of the participant. In a further explanation of this point, Sidman (1994) likened equivalence relations to a kind of *bag* that contained all ordered parts of the events that constitute the relation, and that, all we have to do to document an equivalence relation is to reach into the "bag" and pull out all the pairs. We need to conclude that the elements in the bag do not constitute an equivalence class if any of the pairs in the bag is missing (Sidman, 1994, p. 381).

Though Sidman has strong opinions on his account on equivalence, some crucial questions have been raised about it. For instance, if stimulus equivalence were a fundamental stimulus function, how is it that human participants do not always test positive for equivalence? Also, why do phenomena that equivalence is supposed to underlie not always happen? For instance, why do we not eat the word "bread"?

It is noteworthy, however that, equivalence relations come under contextual control. To say equivalence is a fundamental stimulus function suggests that, equivalence relations emerge first before experience modifies or breaks them down. That is why we don't eat the word "bread", since we would have maybe eaten it, had we not learned through experience or through verbal rules that words, even when equivalent to foods, are not eatable (Sidman, 1992). In another response to these questions, Sidman says:

> "An equivalence relation, therefore, has no existence as a *thing*; it is not actually *established*, *formed*, or *created*. It does not *exist*, either in theory or in reality. It is defined by the emergence of new - and predictable - analytic units of behavior from previously demonstrated units."
> (Sidman, 1994, pp. 387-388).

Contrasting all of the accounts for equivalence, the view that equivalence relations represent a basic behavioral process (Sidman, 1990, 1994, 1997) differs from the relational frame theory (e.g., S. C. Hayes et al., 2001) and the naming hypothesis (Horne & Lowe, 1996) in the sense that, both require a behavioral history for the emergence of stimulus equivalence.

Procedural and other variables that influence equivalence class formation

Though Sidman's original analysis suggested that all procedural artifacts been checked, equivalence relations should emerge immediately, a review of the literature of equivalence research over the last four decades has shown that the likelihood of the formation of equivalence classes is influenced by one variable or another methodological manipulation. Participants in these researches have differed. Experiments have been conducted with typically developing children and adults (e.g.,Arntzen & Lian, 2010; Fields, Arntzen, Nartey, & Eilifsen, 2012) as well as developmentally disabled children and adults (e.g., Arntzen, Halstadtro, Bjerke, & Halstadtro, 2010; Eikeseth & Smith, 1992; Rehfeldt & Dixon, 2005; Steingrimsdottir & Arntzen, 2011). Arntzen (2012) has named such parameters and procedural variables as different training structures, the use of instructions, simultaneous versus delayed matching to sample, the role of familiar stimuli, response requirements for the sample stimulus, and criteria for (a) defining responding in accordance with equivalence and (b) establishing conditional discrimination, as having shown different effects on the likelihood of formation of equivalence classes.

This section will review some of these parameters and how they have influenced the likelihood of formation of classes in different studies.

Type of stimuli. Experiments within stimulus equivalence over the years have been conducted using stimuli with different sensory modalities. Some have used tactile (Belanich & Fields, 1999), visual (Fields et al., 2012; Randell & Remington, 1999; Sidman, Kirk, & Willson-Morris, 1985), olfactory (Annett & Leslie, 1995; Fienup & Dixon, 2006), auditory (Dube, Green, & Serna, 1993), haptic (Tierney, De Largy, & Bracken 1995), and gustatory (L. J. Hayes, Tilley, & Hayes, 1988). Among the visual stimuli reported in the literature so far, some are abstract (Sidman et al., 1982) while others are familiar or meaningful pictures (Arntzen, 2004; Arntzen & Lian, 2010; Fields et al., 2012).

Studies have shown that different types of stimuli may affect the formation of equivalence classes differently with some facilitating the formation of classes whiles others have no such facilitating effect on class formation. The formation of equivalence classes has been reported to be enhanced with the inclusion of a meaningful or familiar picture as a member of the potential class than when all members of the class are abstract stimuli (e.g., Arntzen, 2004; Arntzen & Lian, 2010; Arntzen & Nikolaisen, 2011; Dickins, Bentall, & Smith, 1993; Fields et al., 2012; Holth & Arntzen, 1998; Lyddy, Barnes-Holmes, & Hampson, 2000; Mandell & Sheen, 1994; Travis, Fields, & Arntzen, 2014; Tyndall, Roche, & James, 2004).

Meaningful stimulus. The meaningfulness of a stimulus has traditionally been refereed to its connotative and denotative properties. The denotative properties of a stimulus refer to its associated attributes and feelings (R. Bortoloti & de Rose, 2009) while the denotative properties are the dictionary defining features of the stimulus. In addition to these, the meaningfulness of a stimulus has also been defined by its established behavioral functions. For instance, the acquired discriminative function as well as conditional discriminative functions of a stimulus can define its meaningfulness (Fields et al., 2012; Travis et al., 2014). Thus, meaningfulness is a broad term that encompasses many different aspects. For the purposes of this thesis, meaningful stimuli should therefore be taken as synonymous with familiar pictures and nameable stimuli. They would be used interchangeably throughout this thesis document.

Meaningful stimuli have been used as a node (e.g., Arntzen & Lian, 2010; Fields et al., 2012) or a single (e.g., Arntzen, 2004). A *node* is a stimulus that is related conditionally to more than one other stimulus whereas a stimulus that is related conditionally to just one other stimulus is referred to as a *single* (Fields & Verhave, 1987).

In one such study that has found meaningful pictures as having an enhancing effect on the formation of equivalence classes, Arntzen (2004) reported that one-node five-member equivalence classes were established by 30% of participants when all of the stimuli were meaningless, by 100 % when one familiar picture was used in the first trained baseline relation, and by 50%when the familiar picture was used in the last trained baseline relation. Thus, the inclusion of a meaningful stimulus at different temporal points in training influenced likelihood of equivalence class formation.

In Fields et al. (2012), the effects of the inclusion of meaningful stimuli on the formation of multi-nodal equivalence classes were explored. Participants in the experiment attempted to form three 3-node 5-member equivalence classes after the training of AB, BC, CD, and DE relations in a serial order. None of the participants formed classes when all of the stimuli used were abstract. This was in sharp contrast with when the A, B, D, and E stimuli were abstract shapes while the C stimuli, which served as nodes, were meaningful pictures: 80 % of participants formed classes. Thus, the formation of large multi-nodal classes was also enhanced by the inclusion of a meaningful stimulus as a class member.

In the sequential order of training the baseline relations (e.g., Fields et al., 2012), the order of introduction of the meaningful stimulus may interact with the stimuli and could therefore be a modulator of the meaningfulness of the stimulus. Further studies involving the concurrent training of baseline relations, which will nullify any such order of introduction effect, should be considered to illuminate the class enhancement properties of meaningful stimuli. Also, experiments that will employ the use of meaningful stimuli at different temporal points such as the A, B, C, D, and E members of the to-be-formed equivalence class should be considered to explore its effect on the meaningful stimulus and formation of equivalence classes.

In a series of studies, R. Bortoloti and de Rose (2011) reported a higher transfer of functions in equivalence classes involving happy faces than in equivalence classes involving angry faces using two different methods, namely the semantic differential and the Implicit Relational Assessment Protocol (IRAP). Using these methods for a quantitative assessment of relatedness of semantically similar stimuli, the studies found that the transfer of meaning from the faces to the abstract stimuli was stronger when the classes were established with 2s-delayed matching than when classes were established by simultaneous matching. The results also showed that the transfer of meaning from the faces to the abstract stimuli was an inverse function of nodal distance between them. Thus, the relatedness of equivalent stimuli decreased with nodal distance. The effects of varying delay duration on the formation of equivalence classes or the relatedness of equivalent stimuli as well as the effect of nodal distance are subjects of investigation in this thesis document.

Training protocols. Training protocols concern the sequences of the presentation of the baseline conditional relations as well as which probes for emergent relations are administered and when they are administered (Fields, Reeve, Rosen, Varelas, & Adams, 1997). Three different training protocols have been identified and used in equivalence research so far, namely *simultaneous protocol* (SP), *simple-to-complex* (STC), and *complex-to-simple* (CTS). As Imam (2006) illustrates, the SP is unique in the sense that it trains all the baseline relations first before testing for any of the emergent relations (symmetry, transitivity, or equivalence). The STC and CTS on the other hand differ in terms of what emergent relations are presented after baseline training and when they are administered. In the STC protocol, after baseline relations are trained, test for emergent symmetrical relations are administered. Following that, transitivity is tested, and then finally equivalence test trials are administered. In CTS, equivalence probes are presented immediately after the serial training of the baseline relations

Different outcomes have been reported with the use of different training protocols. There appears to be consensus that, equivalence classes are more readily formed under STC than under CTS protocols (Adams, Fields, & Verhave, 1998) and that, the SP is the least effective protocol in terms of generating equivalence classes (Fields et al., 1997).

Training structures. R. R. Saunders and Green (1999) referred to *training structure* as the sequence of conditional discriminations and the arrangements of common or 'linking' stimuli presented to subjects in baseline training. Three different training structures have been used in the conditional discrimination training in equivalence researches. These are *one-to-many* (OTM), *many-to-one* (MTO), and *linear series* (LS). In OTM, a single stimulus serving as a sample is trained to at least two comparisons. OTM is therefore sometimes referred to as "*sample-as-node*" (K. J. Saunders, Saunders, Williams, & Spradlin, 1993). MTO, on the other hand is termed "*comparison-as-node*" because two samples are trained to one comparison. In LS, a sample is first trained to one comparison, and then that comparison becomes a sample to be trained to another comparison (Fields & Verhave, 1987).

To illustrate, in an equivalence class involving three members indicated by the letters A, B, and C, the training of AB and BC relations before testing for emergent relations represent an LS training structure. MTO involves training of AC and BC relations, and OTM involves training of AB and AC relations (Arntzen, 2012).

Different outcomes have been reported so far in terms of the formation of classes following the presentation of baseline relations with the different training structures. Though there seem to be a general consensus among researchers that the LS is the least effective training structure (Imam, 2006), there are divergent reports on the effectiveness of OTM and MTO. Some studies have reported very little differences between OTM and MTO (Arntzen & Hansen, 2011; Arntzen & Vaidya, 2008; Smeets & Barnes-Holmes, 2005). MTO has been found to be more effective than OTM in some studies (Fields, Hobbie-Reeve, Adams, & Reeve, 1999; R. R. Saunders & Green, 1999; R. R. Saunders, Wachter, & Spradlin, 1988) while OTM has been reported as the most effective in other studies (Arntzen & Holth, 1997, 2000a).

Number of nodes. Closely linked to the training structures are the distribution of singles and the number of nodes in the equivalence class. The effects of the number of nodes used in an experiment has been studied and is found possible when using an LS training structure since OTM and MTO have only one nodes (Fields, Adams, & Verhave, 1993).

Fields et al. (1993) found that increasing the number of nodes in an equivalence class increases *associative distance* and in turn results in a decrease in performance accuracy on tests for emergent relations. Thus, the larger the number of nodes potentially linking stimuli indirectly in training, the less robust the performances on tests for the untrained relations among those stimuli are likely to be. They referred to this as the *nodal distance* effect. Though some papers have reported findings consistent with this (e.g., Arntzen & Holth, 2000b; Fields, Landon-Jimenez, Buffington, & Adams, 1995), others have reported a contrary finding. Imam (2006) controlled for the number of trials by equalizing trials across baseline and emergent relations and concluded that response accuracy did not decrease as a function of nodal number. This finding, thus, supports the reinforcement-contingency explanation of equivalence class membership, which predicts response accuracy and speed to be equal regardless of the nodal number based on equal histories of reinforcement (Sidman, 1994).

As pointed out earlier, meaningful stimuli have been found to have an enhancing effect on the formation of classes when used as nodes (Arntzen & Lian, 2010) and even somewhat as singles (Arntzen, 2004). In both studies, participants attempted to form one-node equivalence classes. The use of meaningful stimuli in the formation of multi-nodal equivalence classes has also been studied. In Fields et al. (2012), participants attempted to form three 3-node 5-member equivalence classes by training AB, BC, CD, and DE relations in a serial order. When all of the Stimuli were abstract, none of the participants formed classes. In contrast, 80 % of participants formed classes when the A, B, D, and E stimuli were abstract shapes and the C stimuli, which served as middle nodes, were meaningful pictures. Thus, the formation of large multi-nodal classes was also enhanced by the inclusion of a meaningful stimulus as a class member.

This thesis document will explore further the use of meaningful stimuli as singles as well as nodes in a multi-nodal class structure. Thus, the effect of the inclusion of a meaningful stimulus at different temporal points in training will be investigated.

Serialized versus concurrent arrangement of training trials. The serialized arrangement of trials involves the gradual introduction of the training trials. Thus, in the ABCDE equivalence class, we will first see the introduction of AB relations repeatedly till the mastery criterion is met, followed by BC in that same arrangement, then CD, and finally DE, before a phase with all of the relations mixed in a random order. Thus, there is a sequential introduction of the training trials in this arrangement. In this thesis document, therefore, *serialized* and *sequential* may be used interchangeably. The concurrent presentation of trials on the other hand involves a presentation of all of the training trials in a random order right from the beginning of the experiment.

Many studies have employed one arrangement or the other depending on what the researcher wants to investigate. However, not even a single paper discussing the arrangement that is more likely to produce equivalence class formation has been published so far. In a recent manuscript, Eilifsen and Arntzen (2014) made a very interesting discussion on the issue. The study investigated the effect of serialized and concurrent arrangements of conditional discriminations on the acquisition of the baseline relations as well as the probability of equivalence class formation. Twenty adults attempted to form three 5-member equivalence classes under a simultaneous protocol. All of the participants were exposed to the two experimental conditions (a serialized arrangement and a concurrent arrangement) with half of them having them in opposing order. The stimuli set used in both conditions were abstract. In both cases, more participants formed classes in the serialized condition than the concurrent condition. With those who started with the serialized arrangement, 30 % formed classes in the serialized condition whiles 10 % formed equivalence classes in the concurrent condition. In the condition that started with the concurrent arrangement, 10 % formed equivalence classes in the concurrent condition whiles 70% formed classes in the serialized arrangement. On the whole, the number of training trials was much fewer in the serialized conditions than in the concurrent condition regardless of which condition was introduced first. Also, irrespective of the order, there were much higher yields when the participants had the serialized arrangement than when they had the concurrent one.

Thus, a sequential or concurrent arrangement of the training trials may have an effect on how fast conditional discriminations are established. It could also have an effect on the establishment of equivalence classes. This will be investigated in this thesis.

Simultaneous Matching to Sample versus Delayed Matching to Sample. In stimulus equivalence research, the presentation of sample and comparison stimuli in conditional discriminations has been arranged as either *simultaneous matching to sample* (SMTS) or *delayed matching to sample* (DMTS). Simultaneous matching refers to the condition where the sample stimulus remains available to the subject throughout each trial until a response is made. Thus, both sample and comparisons are presented at the same time. In DMTS, the sample is removed following the onset of the comparison stimuli, for a response to be made. DMTS experiments have employed either a 0-s delay or an *n*-s delay between the offset of the sample and onset of the comparisons.

The probability of stimulus equivalence class formation as well as the accuracy in baseline conditional discrimination training has been shown to be enhanced following training by DMTS than SMTS (Arntzen, 2006). Furthermore, longer delays have been shown to produce higher yields compared to relatively shorter delays (Arntzen, 2006; Arntzen, Galaen, & Halvorsen, 2007; Vaidya & Smith, 2006).

It is obvious that different processes are at play in the two different procedures and the superiority of the DMTS as compared to SMTS in terms of the generation of equivalence classes could be attributed to the fact that, there is some kind of behavior that goes on the DMTS procedure to fill the gap between the offset of the sample stimulus and the onset of the comparison stimuli (Sidman, 1969). Though the exact nature of this mediating behavior that "fills the gap" is unclear, it could be related to *coding* (Urcuioli, 2013) or *rehearsal* (Arntzen, 2012).

Some of the studies to be presented in this thesis document will explore the effect of these two procedures on equivalence class formation.

Other variables that could influence equivalence class formation

There are several other variables that could influence the formation of classes in one way or the other that have not been mentioned here so far. For instance, the instructions given to participants (Arntzen, Vaidya, & Halstadtro, 2008; Pilgrim, Jackson, & Galizio, 2000; Sidman, 1992), a requirement of a response to sample stimuli (Arntzen, Braaten, Lian, & Eilifsen, 2011; Carlin, Wirth, & Chase, 1998), class size (Arntzen & Holth, 2000b; Fields et al., 1999) among many others have been shown to have some influence on equivalence class formation (see Arntzen, 2012 for an overview of some of these variables).

Though the list cannot be exhausted in this dissertation, it is believed that the variables discussed here are the very crucial ones that will help put the discussion of the different studies presented here in their proper context.

The Studies

General purpose

The general purpose of the series of studies described broadly as the mimicking of meaningfulness is to investigate how portions of the class-enhancing effects of meaningful stimuli can be attributed to different discriminative functions. In an attempt to explore the effects of the inclusion of meaningful stimuli or the discriminative functions as well as all the variables that modulate the class enhancing effect of meaningful stimuli, the studies in this thesis used experimental parameters that will provide a more sensitive measure for such investigation. In all of the studies that will be introduced in this dissertation, participants attempted to form three 3-node 5-member equivalence classes by training AB, BC, CD, and DE relations under the simultaneous protocol. Thus, classes were formed in a multi-nodal linear series training structure represented as A→B→C→D→E.

Main findings

The different studies that make up this thesis will be introduced later and their findings duly discussed in much details. However, this section highlights the findings from the studies; especially how some of the variables and procedural issues mentioned in the introduction influenced the formation of equivalence classes in the studies. I believe this will set the tone for their detailed discussion later.

Some of the main findings are as follows: (a) multi-nodal equivalence classes are less likely to be formed when all class members are abstract stimuli (meaningless); (b) the inclusion of a meaningful stimulus in a multi-nodal class involving other meaningless stimuli helps to convert that class into an equivalence class; (c) greater enhancement of class formation is observed when the meaningful stimulus is included as the middle node rather than as a single; (d) when the meaningful stimulus is included as a single, greater enhancement is observed when it is introduced earlier in the sequential training of baseline relations than when introduced later in the training; (e) pre-training abstract stimuli to acquire meaningfulness prior to class formation enhances the formation of equivalence classes between them and other meaningless stimuli; (f) abstract stimuli that had acquired both successive and simultaneous discriminative functions prior to class formation facilitated class formation that was similar to that found with the inclusion of a familiar picture; (g) pre-training an abstract stimulus with successive discrimination training alone produced higher yields than the pre-training with simultaneous discrimination training alone; (h) pre-training one abstract member of a class with identity or arbitrary relations enhanced subsequent formation of equivalence classes when done with a delayed matching-to-sample procedure than in a simultaneous matching-to-sample procedure; (i) a serialized arrangement of training relations results in a faster acquisition of baseline conditional discriminations, as well as producing greater equivalence yields than a concurrent training of baseline relations;

Some ethical considerations

This research project could not have been complete without some research ethical considerations. As outlined by Bailey and Burch (2005), there are a wide range of very important ethical issues that are generally relevant to every research work. This section of the thesis will discuss a few of them that are relevant to this work.

Informed consent. First of all, it is desired that participants in any study be made to give their informed consent prior to their participation in the study. In that informed consent, full disclosure about the research project is expected to be given by the researcher to the participant using a language that is reasonably understandable to the participant. Participants in this project are university students who are old enough and able to read the consent form and make their own decisions about their participation. The principle of full disclosure, however, was not fully adhered to in this project because I did not intend to tell participants more about the experiment before they participate for fear of confounding the experiment. I believe a full disclosure will clearly defeat my description of participants as naïve in terms of stimulus equivalence research and methodology. Such ethical dilemma according to K. Ruyter (Personal communication, October 3, 2011), should be resolved by making a proportionality assessment between foreseeable benefits and risks, which he explained further to mean “finding the right balance between them”. That assessment in the case of this work shows that the benefits far outweigh any possible risk, if any that the participant will be exposed to by participating in the project.

A debriefing session is scheduled for every participant after completing the experiment to help deal with or reduce any discomfort whatsoever that the participant may have felt during the experiment. During the debriefing, the purpose of the experiment is discussed into much detail and questions from the participant are answered adequately. The results from the experiment is also shown to the participant and discussions as to how and why the participant responded in the manner shown in the results file are made so that participants could leave the experiment as a “happy” person. Every participant is also thanked and given an introductory article on stimulus equivalence to enable them read and gain more understanding about the subject.

Payment and incentives for participants. The duration of the experiment provokes a discussion on certain ethical considerations. Because the experiment can span between an hour and half to two hours and more, there has been discussions about paying the participant in this project to compensate for the time spent and their contributions. Many ethical questions are asked because the decision to pay participants has really facilitated recruitment of participants in previous studies. It therefore makes it difficult to tell whether the guideline to allow for "only a freely given consent and voluntary participation" is not breached, since arguments have been made that the offer of money as compensation for participation could make people sign up against their will. Trying to find what the best things to do to address these ethical concerns, questions have been asked about when is the right time to pay? Should it be before or after the experiment? How much should be paid? Should participants who withdraw after they have started the experiment be paid? In this project, participants were paid 100 Norwegian kroner only after the experiment and were not told about getting paid before they participated in a bid to reduce the risk of people participating against their will. Persons who withdrew before the end of the experiment were also paid for their contribution. Arguments against paying the participants focus on the fact that money could be coercive and may not provide voluntary participation. It should also be said that, trust for the researcher could be more coercive than the payment of participants and that, it is important for the researcher to assess his role in the recruitment of participants as much as he considers paying participants for their contribution. In this experiment, the payment was important not because it may have facilitated recruitment, but as college students who may not have any source of income, paying them could be used to cover travel expenses to get to the laboratory from their homes so that they do not lose anything for participating in the research.

Anonymity of participants. This is another important ethical consideration relevant to this project. It should be impossible for data collected to be traced to any individual participant. However, for purposes of analyzing and reporting data either for academic purposes or for publication in journals, this research project collected personal data such as age and sex of participants. The question therefore is, to what extent will the participant remain anonymous then, if such data are collected? Could these be described as sensitive data? It is important to state that, participants during this experiment were only assigned numbers and the results file produced from the experiment could not be traced to any particular participant even by another colleague researcher in the same laboratory. The information and data from participants were de-personalized in a way so as to make it difficult to link them to participants. Participants were assigned numbers to replace their names to make it difficult to be identified. It is important to state that the details about the type of information taken from participants as well as other details stated in the consent form were approved by the Norwegian Social Science Data Services (NSD).

Privacy. Closely linked to the issue of anonymity is that of privacy which deals with information security in terms of data management and confidentiality. This directs that every information and data from participants in the study be kept properly and not be made public in a way that could reveal participant's identity and results. It is very difficult to determine if this will not be breached due to the fact that members of the laboratory group do meet regularly to discuss data from different studies. Discussing and analyzing the data among the group is itself very important but to reduce the risk of that breaching confidentiality, data to be presented there are de-identified so that no member of the group will be able to trace it to the participant. The storage of the data collected is another important aspect of information security. In this project, results files were kept in an encrypted folder with passwords not available to any other persons and data were not sent to colleagues or supervisors through emails.

Competence of the researcher. Only persons with the relevant qualifications in the field should conduct certain studies or provide treatment. In the case of this project, the researcher has attained the necessary training in stimulus equivalence research and methodology and thus, is well equipped to run these experiments. This is important if the quality of science is to be assured. All of these will tell on how the research is conducted because, an unqualified researcher may not be able to set up the experiment having in mind all the necessary precautions to ensure the comfort and safety of the participants. It is important to set up the experiment in a manner where no unpleasant effect will occur to the participant. The experiments should also be run in a very calm setting. It takes a competent researcher to make adequate provision for all of these in the experiment.

Honesty on the part of the researcher. The quest to obtain very "nice" publishable data could make researchers engage in all sort of unethical behaviors. One could falsify or fabricate data, trim data, or possibly fudge data completely for the prestige associated with publishing and in some cases fulfill organizational objectives. Researchers may also employ wrong statistical tests in their analysis of data collected from their studies just to establish that there is some functional relationship between certain variables whiles actually there isn't any such relationship just to get some publishable data. It is however important to state that, in this research project, we were as objective, unbiased and truthful as possible. It is as a result of this that we as a laboratory group have decided to be as open as possible by discussing data with other colleagues in some of our meetings to serve as a check to prevent bias.

Participant's right to withdraw. Participants are reminded of their right to be able to withdraw from the research at any time during the experiments and also even after the experiment without any consequences should they wish to. This is a fundamental human right that should be easily exercised by any participant. It is however tempting for researchers not to point that out to participants before the experiment for fear of losing them either during or after the experiment especially where access to participants is very difficult. That will be an unethical practice and in this experiment, that right is clearly spelt out to the participant before the experiment and provisions are made to facilitate any participant's withdrawal even after the experiment. This is also a good reason why certain de-identified personal data of participants needs to be taken and kept till data from the research is published, at least.

Plagiarism. There are yet a number of other ethical issues still to be considered even during the writing up of the manuscript for publication. In this thesis document, no work done by another researcher was taken without giving credit. Plagiarism is avoided as much as possible in this project. Even self-plagiarism, the practice of writing one's own earlier work as if they are new is not an acceptable conduct and was avoided. There wouldn't be any circumstance of submitting the same manuscript for publication simultaneously in two or more different journals.

Overview of the studies

This dissertation comprises of a series of studies enumerated as follows:

Study 1 - Nartey, R. K., Arntzen, E., & Fields, L. (2014). Enhancement of equivalence class formation by pre-training discriminative functions. *Learning & Behavior*. doi: 10.3758/s13420-014-0158-6

In this very first study, which is a replication of Fields et al. (2012), we explored how a simple discriminative function acquired by an abstract stimulus through simultaneous and/or successive discrimination training enhanced the formation of an equivalence class of which that stimulus was a member.

Study 2 - Nartey, R.K., Arntzen, E., & Fields, L. (2014). Two discriminative functions of meaningful stimuli that enhance equivalence class formation. *The Psychological Record*. doi: 10.1007/s40732-014-0072-5

Two experiments explored how order of training, familiar pictures, and abstract stimuli that acquired discriminative functions influenced equivalence class formation. In Experiment 1, three 3-node, 5-member equivalence classes (A→B→C→D→E) were established using a training that involved the sequential introduction of the AB, BC, CD, and DE baseline relations in that order, under the simultaneous protocol. Four conditions were studied. In one condition, the A-stimuli were familiar pictures and were members of the first-trained AB relations, while the B-E stimuli were abstract shapes. In a second condition, E-stimuli were familiar pictures and were members of the last-trained DE relations, while the A-D stimuli were abstract shapes. In two matching conditions, abstract stimuli that had acquired discriminative functions (S^Ds) prior to class formation were substituted for the A-stimuli in one condition and E-stimuli in the other condition. Experiment 2 isolated the effects of the order of training the baseline relations by the concurrent establishment of the baselines with the A stimuli as pictures or as S^Ds conditions.

Study 3 - Nartey, R.K., Arntzen, E., & Fields, L. (submitted). Training order and structural location of meaningful stimuli: effects on equivalence class formation

This study explored the effect of the use of a meaningful stimulus as a class member on equivalence class formation. In Experiment 1, fifty university students were trained to form three 3-node 5-member equivalence classes (A→B→C→D→E) under the simultaneous protocol as baseline relations AB, BC, CD, and DE were trained sequentially after which the emergence of all derived relations was tested concurrently. To control for effect of order of training which is confounded in the serialized arrangement of baseline relations, Experiment 2 employed a concurrent training for the establishment of baseline relations for another fifty participants in five groups parallel to the groups in Experiment 1.

Study 4 - Arntzen, E., Nartey, R.K., & Fields, L. (2014). Identity and delay functions of meaningful Stimuli: enhanced equivalence class formation. *The Psychological Record*. doi:10.1007/s40732-014-0066-3

In this study, we investigated whether the acquisition of an identity conditional discriminative function by a meaningless stimulus using simultaneous or delayed matching procedures would influence the likelihood of formation of an equivalence class of which it is a member along with other meaningless stimuli. Forty adults attempted to form 3 three-node five-member equivalence classes (A→B→C→D→E) using the simultaneous protocol. In the PIC group, the C stimuli were pictures and the A, B, D, and E stimuli were abstract shapes. In the ABS group, all of the stimuli were abstract shapes. In the Id-S-MTS (identity simultaneous matching-to-sample) and Id-6sD-MTS (identity 6 s delayed matching-to-sample) groups, prior to class formation, identity conditional discriminations were formed with the C stimuli using simultaneous or 6 s delayed matching-to-sample procedures, respectively.

Study 5 - Arntzen, E., Nartey, R.K., & Fields, L. (submitted). Enhancing responding in accordance with stimulus equivalence by the delayed and relational properties of meaningful stimuli.

This study is a replication of Study 4 with an extension to include two new groups. Sixty participants (10 each in 6 groups) attempted the formation of 3 three-node five-member classes. In the ABS group, all stimuli used (A-E) were abstract shapes, whiles in the PIC group, the C stimuli were pictures and the A, B, D, and E stimuli were abstract shapes. In the Id-S-MTS (identity simultaneous matching-to-sample) and Id-6sD-MTS (identity 6 s delayed matching-to-sample) groups, prior to class formation, identity conditional discriminations were formed with the C abstract stimuli using simultaneous or 6 s delayed matching-to-sample procedures, respectively. The two new groups studied here involved the establishment of arbitrary (ARB) conditional discriminations with a new set of abstract stimuli. Prior to class formation, arbitrary conditional discriminations were formed with the C- abstract stimuli using simultaneous and 6 s delayed matching-to-sample procedures in the ARB-S-MTS (arbitrary simultaneous matching-to-sample) and ARB-6sD-MTS (arbitrary 6 s delayed matching-to-sample) groups respectively.

General Discussion

The series of experiments outlined in this thesis document sought to investigate how portions of the class-enhancing effects of meaningful stimuli can be attributed to different discriminative functions. Thus, different discriminative functions were pre-trained with meaningless stimuli and subsequently used in equivalence class formation to determine if they could acquire some functions as meaningful stimuli. In this section, I will present a brief summary of all the studies and follow it up with a discussion of some of the major findings from them.

In the first study, we investigated the differential effects of pre-training with simultaneous discriminations and/or successive discrimination on the subsequent formation of 3-node 5-member classes (A→B→C→D→E) using the simultaneous protocol. This was a replication of Fields et al. (2012). Fifty college students were randomly assigned to five different groups: Abstract C stimulus (ABS), Meaningful C stimulus (PIC), Abstract C pre-trained with both simultaneous and successive discrimination (SIM+SUCC), Abstract C pre-trained with simultaneous discrimination only (SIM-only), and Abstract C pre-trained with successive discrimination only (SUCC-only). Thus, in the PIC group, the C stimuli were pictures and the A, B, D, and E stimuli were abstract shapes while in the ABS group, all of the stimuli were abstract shapes. In the SIM+SUCC group, simple discriminations were formed with the C-stimuli through both simultaneous and successive discrimination training before class formation. Finally, in the SIM-only and SUCC-only groups, prior to class formation, simple discriminations were established for the C-stimuli with a simultaneous procedure and a successive procedure respectively. Results from the study showed that: (1) Very few formed classes when the middle nodes as well as the other class members were abstract and meaningless stimuli (ABS). (2) Most participants formed classes when the middle node in the class was a familiar picture (PIC) and the other class members were abstract stimuli. (3) Abstract stimuli that had acquired successive and simultaneous discriminative functions (SIM+SUCC) prior to class formation facilitated class formation that was similar to that found when the middle node was a familiar picture. (4) When either the successive or the simultaneous discriminative function was acquired by an abstract stimulus alone, the successive discrimination training (SUCC-only) produced higher yields than the simultaneous discrimination training (SIM-only). (5) The sum of the two yields produced by the separate discriminations was not as large as that produced by the establishment of both discriminative functions. (6) Finally, a sorting test confirmed the formation of these classes by all the participants that formed classes during the derived relations test.

In two experiments, Study 2 explored how the order of training, familiar pictures, and abstract stimuli that acquired discriminative functions influenced equivalence class formation. In Experiment 1, three 3-node 5-member equivalence classes (A→B→C→D→E) were established under the simultaneous protocol with the sequential training of the AB, BC, CD, and DE baseline relations in that order, after which the emergence of all derived relations were tested on a concurrent basis. Participants were assigned on a block randomized basis to one of four different conditions; (1) Meaningful A stimulus (A-as-PIC); (2) Meaningful E stimulus (E-as-PIC); (3) Acquired Discriminative Function of A- abstract stimulus (A-as-S^D); and (4) Acquired Discriminative Function of E abstract stimulus (E-as-S^D). Thus, the participants in the Meaningful A stimulus condition, attempted to form equivalence classes that consisted of an A stimulus that was meaningful, and B, C, D, and E stimuli that were abstract shapes. Those in the E-as-PIC condition attempted to form equivalence classes that consisted of A, B, C, D stimuli that were abstract shapes, and an E stimulus that was a meaningful picture. For participants in the

A-as-S^D and E-as-S^D conditions, attempts were made to form equivalence classes that consisted of abstract stimuli only, after the A or E stimuli, for the A-as-S^D or E-as-S^D conditions respectively, have been established as S^Ds. Classes were formed by 70% of participants when the A-stimuli were familiar pictures and were members of the first-trained AB relations, while the B-E stimuli were abstract shapes. Classes were formed by 40% of participants when the E-stimuli were familiar pictures and were members of the last-trained DE relations while the A-D stimuli were abstract shapes. When abstract stimuli that had acquired discriminative functions (S^Ds) prior to class formation were substituted for the A and E stimuli, classes were formed by 20% of participants in each condition. Furthermore, greater enhancement effects were obtained using pictures than abstract stimuli that have acquired discriminative functions when these stimuli were the A members of the classes, while no differences in yield were observed when they were the E members of the classes. Also, there was a 92% concordance between a final sorting task produced by the participants and their performances in the derived relations tests. The results suggest that the probability of class formation could have been influenced by the position of a meaningful stimulus or an S^D in the structure of a class (i.e., A or E) and/or their order of introduction during training (first or last). In Experiment 2, we isolated the effects of these variables by establishing the baseline relations on a concurrent basis with the A stimuli as pictures or as S^Ds. Results from Experiment 2 showed no participant formed classes in either condition and suggest that the class enhancement by a meaningful stimulus depended on its inclusion in the first trained baseline relation and not its mere placement in the class structure.

In Study 3, we explored the effect of the use of a meaningful stimulus as a class member on equivalence class formation. In Experiment 1, fifty university students were trained to form three 3-node 5-member classes (A → B → C → D → E) under the simultaneous protocol.

Baseline relations AB, BC, CD, and DE were trained sequentially after which the emergence of all derived relations were tested concurrently. Classes were formed by 70% of participants when all C members of the class were meaningful pictures whiles A, B, D, and E were abstract stimuli. Classes were formed by 60 % of participants when the A-stimuli were familiar pictures and were members of the first-trained AB relations, while the B-E stimuli were abstract. Classes were formed by 40 % of participants when the B or D stimuli were familiar pictures while the other stimuli were abstract. When the E-stimuli were familiar pictures and were members of the last-trained DE relations, while the A-D stimuli were abstract, classes were formed by 20 % of participants. The results suggest that class enhancement by a meaningful stimulus did not depend on its mere inclusion in the class; rather, enhancement was influenced by the position of the meaningful stimulus in the structure of the class and/or its order of introduction during training. Experiment 2 controlled for the order of introduction effect by training the baseline relations on a concurrent basis. Fifty university students were randomly assigned to five groups that paralleled the groups in Experiment 1. None of the participants formed classes in the B-as-PIC, D-as-PIC, and E-as-PIC groups. Classes were formed by 10 % of participants when the A- members of the class were meaningful pictures whiles B-E stimuli were abstract, and by 20 % of participants when the C-members were meaningful and the A-, B-, D-, and E- members were abstract. Thus, no class enhancement was produced when training was done concurrently. This therefore validates the findings of Experiment 1 that, the class enhancement produced by the inclusion of a meaningful stimulus after the serial training of baseline relations is modulated by the order of introduction of the meaningful stimulus during training and not its mere inclusion in the structure of the class.

In the fourth study, we determined whether the prior establishment of an identity relation with one meaningless stimulus using simultaneous or delayed matching procedures would influence the likelihood of forming an equivalence class that contained that stimulus and other meaningless stimuli. In all four groups, participants attempted to form three 3-node 5-member equivalence classes that contained stimuli designated as A, B, C, D, and E. Training and testing were conducted under the simultaneous protocol. In three groups, the stimuli were abstract or meaningless shapes. In the fourth, the classes contained the same A, B, D, and E stimuli, but the C stimuli were familiar and meaningful pictures. In the ABS group, all of the stimuli were abstract shapes. In the PIC group, participants attempted to form classes with abstract A, B, D, and E stimuli and a meaningful picture as the C stimulus. In the Id-S-MTS (identity simultaneous matching-to-sample) and Id-6sD-MTS (identity 6 s delayed matching-to-sample) groups, prior to class formation, identity conditional discriminations were formed with the C stimuli using simultaneous or 6 s delayed matching-to-sample procedures, respectively. Classes were formed by 80% and 60 % of participants in the PIC and delayed identity groups, and by 0% and 10 % of participants with no prior training (ABS group) or after forming identity relations on a simultaneous basis. The results, thus, showed how the prior formation of identity conditional relations in simultaneous and delayed MTS formats influenced subsequent likelihood of equivalence class formation.

In a replication of Study 4, Study 5 extended the establishment of pre-class formation identity conditional relations to arbitrary stimuli and subsequently investigated its influence on equivalence class formation. Participants were trained to form three 3-node 5-member equivalence classes that contained stimuli designated as A, B, C, D, and E under the simultaneous protocol. Two new groups were studied in addition to the original four groups. As in Study # 4, in the ABS group, all of the stimuli were abstract shapes. In the PIC group, participants attempted to form classes with abstract A, B, D, and E stimuli and a meaningful picture as the C stimulus. In the ABS Id-S-MTS (abstract identity simultaneous matching-to-sample) and ABS Id-6sD-MTS (abstract identity 6 s delayed matching-to-sample) groups, prior to class formation, identity conditional discriminations were formed with the C stimuli using simultaneous or 6 s delayed matching-to-sample procedures, respectively. In the two new groups, ARB Id-S-MTS (arbitrary identity simultaneous matching-to-sample) and ARB Id-6sD-MTS (arbitrary identity 6 s delayed matching-to-sample) groups, identity conditional discriminations were formed with the C- arbitrary stimuli with simultaneous or 6 s delayed matching-to-sample procedures, respectively, prior to class formation. In the ABS group, where no prior training was done, classes were formed by 0% of participants while 80% of participants in the PIC group formed classes. When identity relations were established for abstract C stimuli, classes were formed by 0% and 40% of participants when done on a simultaneous basis and in a delayed procedure, respectively. When identity relations were established for arbitrary stimuli, 20% of participants formed classes when done on a simultaneous basis while 50% formed classes when established on a delayed basis. Results from this study corroborate the findings of Study # 4 as the subsequent likelihood of equivalence class formation is influenced more by the prior formation of identity conditional relations in delayed MTS format influenced than in simultaneous MTS format.

All of the studies presented in this thesis highlight the class enhancing influence of meaningful stimuli. Among the general findings throughout the different studies are: (1) multi-nodal equivalence classes are less likely to be formed when all potential class members are abstract or meaningless stimuli; (2) the inclusion of a meaningful stimulus in a set of other meaningless stimuli is shown to be very influential in the formation of multi-nodal equivalence classes; (3) different acquired discriminative functions could account for portions of this class enhancing properties manifested by meaningful stimuli; and (4) a post-class formation sorting test confirmed or documented the maintenance of the classes that are formed under the derived relations tests.

Effects of meaningful stimuli on equivalence class formation

A very small proportion of participants formed equivalence classes when training involved the use of abstract stimuli only. In contrast, most of the participants formed equivalence classes when meaningful pictures were included in the set of other meaningless stimuli. Thus, the inclusion of a meaningful stimulus in a class of meaningless stimuli helps to convert the whole class into an equivalence class. How this conversion is done is speculative. However, meaningful pictures are assumed to be associated pre-experimentally with many other stimuli and thus, they likely form categories with their associated stimuli, akin to generalized equivalence classes (Fields, 2009; Galizio, Stewart, & Pilgrim, 2004). Hence, the familiar pictures become conditionally related to the other abstract stimuli and thus, also become functionally interchangeable with each other (Tyndall et al., 2004). Following this, Fields et al. (2012) therefore suggests that the ‘‘formation’’ of each five-member class that consisted of four abstract stimuli and a picture is probably a case of expansion of an already existing stimulus class by the addition of the four abstract stimuli rather than the “new” formation of a five-member equivalence class.

The same argument could be made in favor of the class enhancing effect that is seen with the inclusion of abstract stimuli that had acquired different discriminative functions prior to the formation of classes. Additional research is however required to test this proposition.

Modulation of class enhancement by meaningful stimuli

One of the findings of the current studies is that, meaningful stimuli do not necessarily produce class enhancement due to their mere inclusion in a class or set of other meaningless stimuli. Different parts of the studies presented here suggest that the class enhancement of these meaningful stimuli are modulated by different structural aspects of the equivalence class, the order of introduction of the meaningful stimulus, and/or its structural location in an equivalence class, as well as certain other functions and properties they have. Thus, there are other vital determinants of the class enhancing effects of these meaningful stimuli.

In Experiment 1 of Study 2, three 3-nodes, 5-member equivalence classes (A→B→C→D→E) were established through the serialized training of the AB, BC, CD, and DE baseline relations. In one group, the A-stimuli were familiar pictures and were members of the first trained AB relations, while the B-E stimuli were abstract stimuli (A-as-PIC). In another group, the E-stimuli were familiar pictures and were members of the last trained DE relations, while the A-D stimuli were abstract stimuli (E-as-PIC). Classes were formed by 70 % of participants in the A-as-PIC group while 40 % of participants in the E-as-PIC group formed classes. It is possible that, the likelihood of class formation could have been influenced by the position of a meaningful stimulus in the structure of a class (i.e., A or E) and/or their order of introduction during training (first or last). In an effort to wash away any order of introduction effect, Experiment 2 established baseline relations on a concurrent basis for the A-as-PIC and A-as-S^D groups. No participants formed classes in either group .Thus, class enhancement by a meaningful stimulus depended on its inclusion in the first trained baseline relation and not its mere placement in the class structure.

In an extension of this finding, Experiment 1 in Study 3 studied the formation of three 3-node 5-member equivalence classes (A → B → C → D → E) under the simultaneous protocol with five groups of ten participants each. The groups varied in terms of the member of the class of other meaningless stimuli that was represented by a meaningful stimulus. Thus, in the different groups, the meaningful stimulus was included in the set of other meaningless stimuli as the A, B, C, D, or E member of a to-be-formed class. After the serial training of the baseline relations AB, BC, CD, and DE, 60% of participants formed classes in the A-as-PIC group. Forty percent formed classes in the B-as-PIC and D-as-PIC groups. When C was meaningful and the rest were meaningless (C-as-PIC), classes were formed by 70% of participants, while 20% of participants formed classes in the E-as-PIC group. These results suggest that class enhancement was modulated by either the order of training the relation that included the meaningful stimulus, and/or the location of the meaningful stimulus in the nodal structure of the class. Experiment 2 controlled for the effect of order of introduction through the concurrent training of all the baseline relations in five new groups that paralleled those in Experiment 1. Regardless of the location of the meaningful stimulus in the class structure (A-E), classes were formed by 0-20% of the participants. Experiment 2, thus, validates the findings of Experiment 1 that, the mere inclusion of a meaningful stimulus does not always enhance the formation of an equivalence class.

Studies 2 and 3, therefore, constitute an elegant illustration of the modulation of the class enhancement of meaningful stimuli by their order of introduction and/or their structural location in the nodal structure of the class during the serial training of the baseline relations.

In the nodal structure employed in the studies presented here, A and E members are referred to as singles, while B, C, and D members are nodes. The C-members of the class are therefore middle nodes while B- and D- are end nodes. Employing a meaningful stimulus as the A, B, C, D or E member of the class has different consequences. Considering the singles for instance, Study 2 used a meaningful stimulus as the A-member and a part of the first trained AB relation and as the E-member and a part of the last trained DE relation. Seventy percent of participants formed classes when the meaningful picture was the A-member of the class while 40 % formed classes when used as the E-member of the class. Both of them being singles, you would envisage similar effect on equivalence class formation. This suggests that, as the A-stimulus and a member of the first trained relation, it served as a lead stimulus or an anchor in the training structure; a function that was not present with the late introduction of the meaningful stimulus as the E-stimulus and a member of the last trained relation. Thus, there is a primacy effect as it is part of the first trained relation .This was confirmed by Study 3, which studied the effect of having the meaningful stimulus as the A, B, C, D, or E member of the class in one experiment. In effect, the status of the A stimulus as a lead stimulus in the structure and as a member of the first trained relation overshadowed the absolute single status of the stimulus.

Across the different studies, having meaningful stimuli as nodes generally facilitates equivalence class formation. When the effects of having the meaningful stimuli as nodes are compared, middle nodes have produced the highest yields as compared to the end nodes. In Study 3, the class formation was more likely when the meaningful picture was the C-stimulus instead of the B- or D- stimuli. This suggests that having the meaningful stimulus as the middle node, one that is linked to two other nodes is more advantageous, than as end nodes, nodes linked to one other node and one single. As a middle node, there was an equal associative distance (Fields & Verhave, 1987) from the C stimulus to all of the stimuli involved in the transitive and equivalence relations which is not the same with the B-or D- stimuli. This means that the class enhancement of nodal meaningful stimuli is modulated by its inclusion as the middle node rather than its absolute status as a node.

Concluding on the modulation of the class enhancing effect of meaningful stimuli, it is important to note that, the non-monotonic effect of the meaningful stimulus on likelihood of equivalence class formation and a consideration of the training structure, nodal function of stimuli and training order probably interacts with the meaningful stimulus and its point of insertion to account for the class enhancement.

Properties of meaningful stimuli

As pointed out earlier in the introduction, as far as the properties of meaningful stimuli are concerned, we have traditionally referred to their connotative (associated attributes and feelings) and their denotative (dictionary defining features) properties. The current studies have extended our knowledge about these properties to include other established behavioral properties or functions. For instance, in Fields et al. (2012), participants were thought to form three ABCDE equivalence classes under the simultaneous protocol. None of the participants formed classes when all the stimuli were all abstract shapes. In contrast, when the A, B, D, and E stimuli were abstract shapes and the C stimuli were meaningful pictures, 8 of 10 participants formed classes. When A–E stimuli were abstract shapes and the C stimuli became S^Ds prior to class formation, 5 out of 10 participants formed classes. Travis et al. (2014) and Study 1 in the current dissertation replicate this finding and thus, suggest that, the acquired simple discriminative functions as well as conditional discriminative functions of a stimulus can also define its meaningfulness.

Naming and the formation of equivalence classes

The role of naming on the formation of equivalence classes has been discussed in many studies (e.g., Bentall, Dickins, & Fox, 1993; Dickins et al., 1993). The discussion will continue here because results from some of the studies presented here have some implications for the naming account. Going by the naming proposition, the inclusion of a nameable stimulus per se should enhance class formation. However, results from Studies 2 and 3 show its late introduction obviate the class enhancing effect of naming, which provide an important limitation to the naming theory of equivalence class formation.

Though speculative, participants are more likely to assign the same names to stimuli belonging to the same class (homogeneous naming) when the nameable stimuli are introduced earlier. On the other hand, it may be that, before the nameable pictures are introduced at the end of the training, the participants may have named the various stimuli in their own ways, which will more likely be heterogeneous (thus, each individual stimuli being named differently). On that basis, it is easier to say that the earlier introduction of the nameable stimuli will facilitate the formation of equivalence classes while a late introduction of the nameable stimuli will be difficult for the participant since the kind of stimulus control that had long being established through the individual naming of the stimuli will suddenly have to come under the control of a new set of names when the pictures are finally introduced. This corroborates the findings of Bentall et al. (1993) and Dickins et al. (1993) that, group names could function like shared membership of natural categories that will facilitate the formation of equivalence classes while individual names show no evidence of a role in the development of emergent linkages between the stimuli involved.

However, if naming is critical, then its point of introduction should not be crucial as naming early should be as important as naming in the middle or at the end. These data would therefore modulate the naming account since naming at the end loses influence and will therefore support the views of Sidman (1994) that naming could be facilitative but not a necessary prerequisite for the formation of equivalence classes.

Effects of serialized and concurrent training on the acquisition of conditional relations and the formation of equivalence classes.

As suggested earlier in the introduction, the different arrangements of trials during the training of baseline relations may have some consequences on the speed of acquiring the baseline conditional relations, and/or the formation of equivalence classes. Considerable evidence for this analysis can be sought from Studies 2 and 3, where both serialized and concurrent training were employed to establish baseline relations. In Study 3for instance, when the performances of participants in Experiment 1 who had a serialized arrangement are compared to the performances of a parallel group of participants in Experiment 2, who had a concurrent arrangement (see Figure 4), the acquisition speed was generally faster for the participants in the serialized arrangement than those in the concurrent arrangement. Also, there was a significant difference between the two arrangements in terms of the errors made during the acquisition of the baseline relations. Ultimately, many participants formed classes in each group with the serialized arrangement compared to its parallel group in the concurrent arrangement. These outcomes are consistent with that reported by Eilifsen and Arntzen (2014).

In the serialized arrangement, participants are exposed to a fewer number of discriminations from the beginning in serialized arrangements which makes the establishment of conditional discriminations a lot easier than in the concurrent arrangements, where all baseline conditional discriminations are introduced together from the first training block. This implies that, many trials in the serialized arrangement will occasion reinforcement than in the concurrent arrangement and may contribute to the fact that the relations are established much faster in serialized arrangement as compared to the concurrent arrangement.

Because Sidman (2000) postulates that, following the establishment of conditional relations, the emergence of derived relations should be observed unless specified contextual variables cause the breakdown of the equivalence classes, it is a bit surprising to see different outcomes on the formation of equivalence classes. As in the current studies, following the two different arrangements, in almost all cases regardless of the kind of arrangement, the baseline relations were maintained and intact before the introduction of the test for derived relations. Why the formation of equivalence classes was difficult in the concurrent arrangement is still an issue to be investigated. Further research into this should be designed to identify the contextual variables that may have caused the breakdown of the equivalence classes in the concurrent arrangement.

Effects of SMTS and DMTS

Studies 4 and 5 investigated whether the prior establishment of an identity or arbitrary relation with one meaningless stimulus using simultaneous or delayed matching procedures would influence the likelihood of forming an equivalence class that contained that stimulus and other meaningless stimuli. The prior establishment of identity or arbitrary relations on a delayed basis (Id-6sD-MTS and Arb-6sD-MTS) produced enhancement similar to that produced by meaningful pictures, while no class enhancement was produced when the identity or arbitrary function was established with no delay (Id-S-MTS and Arb-S-MTS). As mentioned in the introduction and discussed in Study 4, some sort of mediating behavior such as coding or rehearsal that was only possible during the delay may have accounted for the class enhancement following the delay function.

There were no significant differences in terms of the yields produced by the prior establishment of identity and arbitrary relations on SMTS basis on one hand and between the identity and arbitrary relations established by DMTS on the other hand. This therefore implies that the delay function is responsible for the class enhancement and not the type of conditional relations established – identity or arbitrary. Additional research is however needed to validate these findings.

Card Sorting

The concordance between the MTS emergent relations test performances and the performances documented by the post class formation card sorting reported by Fields et al. (2012) has been replicated by several studies (e.g., Arntzen, Nartey, & Fields, 2014b; Fields, Arntzen, & Moksness, 2014; Nartey, Arntzen, & Fields, 2014c). In the studies presented herein, participants used an average duration of three minutes to complete the sorting test as compared to about 30 minutes in the MTS test for emergent relations. It has therefore led to a suggestion that, the sorting test could provide a quick evaluation of equivalence class formation and could maybe be used to save time instead of administering the MTS emergent relations test. Though Fields et al. (2014) admits that the sorting test does not evaluate all the test relations that are evaluated by the MTS emergent relations test, it is tempting to say that the high concordance between the two test formats mean that, test for emergent relations does not require an evaluation of all relations. Specifically, the sorting tests evaluates all baseline, symmetrical, transitive, and equivalence relations but not reflexive relations. This may have implications for the number of relational types that should be used to document the emergence of equivalence classes even in the MTS format. Additional research should administer the sorting test immediately after the establishment of the baseline relations in the MTS followed by a number of sorting tests evaluating all the different relational types to check if all the relational types are needed for the evaluation of equivalence class formation.

Conclusion

The series of studies presented in this thesis document have strengthened the finding that the inclusion of a meaningful stimulus in a set of other meaningless class enhances the formation of equivalence classes. The inclusion of the meaningful stimulus alone has however been demonstrated as insufficient to generate the class enhancement. Rather, the class enhancement of a meaningful stimulus is modulated by its order of introduction in the serial training of the baseline relations for a class, the structural location of the meaningful stimulus in the training structure as well as its behavioral functions. When some pre-existing properties and functions of meaningful stimuli were established with abstract (meaningless) stimuli prior to their inclusion as members of equivalence classes together with other meaningless stimuli, the formation of classes was enhanced to the levels similar to that observed by the inclusion of meaningful stimuli. Thus, the acquired simple successive discriminative functions, delayed identity and arbitrary functions as well as the traditional connotative and denotative properties of meaningful stimuli are the crucial properties that influence the class formation. Finally, a sorting test that documented the maintenance of the performances in the MTS emergent relations test indicate that class based behavior generalized between two trial formats: matching to sample trials during class formation and sorting during post class formation testing.

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Study 1

Enhancement of Equivalence Class Formation by Pre-training Discriminative Functions

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Abstract

The present experiment showed how a simple discriminative function acquired by an abstract stimulus through simultaneous and/or successive discrimination training enhanced the formation of an equivalence class of which that stimulus was a member. College students attempted to form three 3-node 5-member equivalence classes (A→B→C→D→E) using the simultaneous protocol. In the PIC group, the C stimuli were pictures and the A, B, D, and E stimuli were abstract shapes. In the ABS group, all of the stimuli were abstract shapes. In the SIM+SUCC (simultaneous and successive) group, simple discriminations were formed with the C stimuli through both simultaneous and successive discrimination training before class formation. Finally, in the SIM-only and SUCC-only groups, prior to class formation, simple discriminations were established for the C stimuli with a simultaneous procedure and a successive procedure respectively. Equivalence classes were formed by 80% and 70% of participants in the PIC and SIM+SUCC groups, by 30% in the SUCC-only group, and by 10% of participants in the ABS and SIM-only groups. Thus, pre-training of the combined simultaneous and successive discriminations enhanced class formation as did the inclusion of a meaningful stimulus in a class. The isolated effect of forming successive discriminations was more influential than that of forming simultaneous discriminations. The establishment of both discriminations together produced a greater enhancement than the sum of the two procedures alone. Finally, a sorting test documented the maintenance of the classes formed during the simultaneous protocol. These results also provide a stimulus control function account of the class enhancing effects of meaningful stimuli.

Key words: Meaningfulness, stimulus equivalence, simultaneous discrimination, successive discrimination, pictures, sorting tests, college students.

When the relations among a finite set of perceptually disparate stimuli can show the properties of reflexivity, symmetry, and transitivity, alone and in combination, those stimuli are said to be equivalent to each other and are acting as members of an equivalence class (Sidman & Tailby, 1982). These stimuli then can be used substitutably or interchangeably with each other. For instance, if stimuli are represented by the letters A, B, D, C, and E, after the training of the conditional relations AB, BC, CD, and DE, their functionality as members of an equivalence class would be documented by the emergence of the untrained derived reflexive relations (AA, BB, CC, DD, and EE), symmetrical relations (BA, CB, DC, and ED), transitive relations (AC, AD, AE, BD, BE, and CE), and equivalence relations (CA, DA, EA, DB, EB, and EC) (Fields & Verhave, 1987; Sidman, 1994; Sidman & Tailby, 1982). When such a class is formed, the stimuli can be substituted for each other in new settings, and typically a response trained to one stimulus will also be evoked by the other stimuli in the class without benefit of additional direct training; the class then acts as a response transfer network.

In basic research settings, it is usual to establish classes amongst stimuli in set of nominally meaningless stimuli. When attempts to form classes are made using the simultaneous protocol, which involves firstly the training of all baseline relations and then the testing of all derived relations together with the baseline relations, typically, the classes are quite unlikely to be formed. On the other hand, the inclusion of a meaningful stimulus in a set of other meaningless stimuli enhances the likelihood of class formation (Arntzen, 2004; Arntzen & Lian, 2010; Fields et al., 2012; Nartey et al., 2014c), whether the meaningful stimulus was used as a node (Arntzen & Lian, 2010; Fields et al., 2012) or a single (Arntzen, 2004; Nartey et al., 2014c).

Meaningful stimuli, however, can serve at least two discriminative functions: that of a simple successive discrimination and/or that of a simple simultaneous discrimination (Fields et al., 2012; Travis et al., 2014) . Thus, the class enhancing effect of a meaningful stimulus could be attributed to either or both of its presumed discriminative functions. Fields et al. (2012) showed that the formation of an equivalence class (ABCDE) that consisted of meaningless stimuli was enhanced by the pre-class establishment of both discriminative functions with an abstract C stimulus. This finding supported the view that the class enhancing effects of a meaningful stimulus can be accounted for in part by the discriminative functions served by meaningful stimuli.

As noted above, a simple discrimination can be established on a successive or a simultaneous basis. In a simple successive discrimination, the S^D and S^Δ are presented separately and a reinforcer is presented only if a particular response occurs in the presence of the S^D. Such a discrimination is formed when the response comes to occur more often in the presence of the S^D than in the presence of the S^Δ (Mcllvane, 2013; R. R. Saunders & Green, 1999). In a simultaneous discrimination, the S^D and S^Δ are presented concurrently on each trial, and reinforcement is presented for the selection of the S^D. Such discrimination is formed when the S^D is selected on more trials than the S^Δ (Mcllvane, 2013; R. R. Saunders & Green, 1999).

Fields et al. (2012) studied how the combined acquisition of simultaneous (SIM) and successive (SUCC) discriminative functions by an abstract stimulus prior to equivalence class formation enhanced the formation of classes that included these stimuli. When the A–E stimuli were all abstract shapes, none of the participants formed classes. When the A, B, D, and E stimuli were abstract shapes and the C stimuli were meaningful pictures, 80% of the participants formed classes. When the A–E stimuli were abstract shapes and the C stimuli became S^Ds through the training of both simultaneous and successive discriminations prior to class formation, 50% of participants formed classes. That experiment, however, did not identify the class enhancing effects of the pre class formation establishment of the successive and the simultaneous discriminations in isolation. Travis et al. (2014) extended that analysis by exploring the effects of some but not all of those possibilities. In that study, they assessed the effect of SIM+SUCC discrimination training, and SIM-only, but not the effects of SUCC-only.

The present experiment explored all of those possibilities. Participants attempted to form three 3-node 5-member equivalence classes by the sequential training of AB, BC, CD, and DE relations, after which the emergence of the classes was assessed with a test that involved the presentation of all emergent relations probes in the same test block. Five different pre-class formation discrimination training conditions were studied with the first three being direct replications of the conditions explored by Fields et al. (2012). In the ABS group, the A–E stimuli represented abstract shapes that were difficult to name, and thus, nominally meaningless. In the meaningful stimulus (PIC) group, the C stimuli were nameable and meaningful pictures, while the A, B, D, and E stimuli were the same abstract shapes used in the ABS group. In the SIM+SUCC group, the C stimuli were established as S^Ds using both simultaneous and successive discrimination training prior to class formation. The present experiment also isolated the class enhancing effects of successive discrimination training alone in a SUCC-only group, and simultaneous discrimination training alone in a SIM-only group. A comparison of the likelihoods of class formation by each of these conditions indicated how SIM+SUCC discrimination training alone and in combination enhanced the formation of equivalence classes. These results would also indicate how these discriminative functions presumably served by meaningful stimuli could account for the enhancement of equivalence class formation by meaningful stimuli.

Method

Participants

Fifty university students (25 males and 25 females) between the ages of 19 and 23 years old participated voluntarily in this study ($M = 21$, $SD = 1.15$). The participants had no prior knowledge of stimulus equivalence research and methodology. Four other participants who started the experiment either quit or were dismissed because they did not acquire the baseline relations after 2 hours of training and new participants were recruited to replace them. Participants were assigned on a block-randomized basis to one of five experimental groups and experimental sessions were run individually.

Apparatus

Setting. The experiments were conducted in the graduate seminar room of the Department of Psychology at the University of Ghana, Legon which measured approximately 5m square and was furnished with tables and chairs.

Hardware. An HP Compaq nc6320 laptop computer that used an 1828 MHz Intel Centrino® processor, and had a screen with a 16.8 in diagonal length and a 16 × 9 horizontal-to-vertical ratio was used to conduct the experiments. An external mouse was used by participants to control the position of the cursor throughout the experiment.

Software. A software program version 3.12 made by Psych Fusion Software in collaboration with second author was used in the training and testing of all conditional discriminations for all of the participants. The software controlled the presentation of all stimuli and also made recordings of data including the trial number, number of training trials, reaction time to sample and comparison stimuli, whether or not participants made the correct/incorrect comparison choice, and whether or not programmed consequences was delivered. This software provided a summary of symmetry and all derived relations tests as well as the duration of the experiment.

Stimuli. Figure 1 shows the stimulus sets used in the experiment. In the top two sections of the figure are the stimuli 15 abstract and the 3 familiar picture-stimuli used as members of the equivalence classes while the bottom section shows the stimuli used during discrimination training. The abstract stimuli were displayed in black and the picture stimuli in colors, both on a white background. Small plastic-laminated pictures sized 3.8cm square were made from the 15 abstract stimuli and the pictures to be used in the experiment. The size of the touch sensitive areas on the screen was 9.4cm x 3.4 cm.

Procedure

Design. The participants were assigned on a block-randomized basis to one of five conditions: (1) Abstract C stimulus (ABS), (2) Meaningful C stimulus (PIC), (3) Abstract C pretrained with both simultaneous and successive discrimination (SIM+SUCC), (4) Abstract C pretrained with simultaneous discrimination only (SIM-only), and (5) Abstract C pretrained with successive discrimination only (SUCC-only.)

Informed consent. All participants were asked to take a seat and given an informed consent document to read upon arrival at the experimental setting. The consent document informed participants that they were about to participate in an experiment in the field of behavior analysis, and that it will last approximately one and half-hours. They also read that they were required to respond to certain stimuli on the screen of a computer with mouse clicks and that, there were no known harmful effects of participating in the study. Participants were also informed that they were free to withdraw from the experiment at any time without any negative consequences. After reading, those who agreed participate signed the forms and began the experiment.

Categorization test: Card sorting. After signing the informed consent document, the participants remained seated in the experimental cubicle and were given the 15 plastic-laminated cards that corresponded to the stimuli to be used in the condition to which the participant was assigned and told to "put them into groups". Participants in the ABS, SIM+SUCC, SIM-only and SUCC-only conditions were presented with 15 abstract stimuli cards, while those in the PIC condition were given 12 abstract stimuli and the three picture C stimuli. They were asked to "put them into groups" again after the experiment.

Instructions. Participants remained seated behind the computer and were presented with the following instructions on the computer screen:

> "In a moment a stimulus will appear in the middle of the screen. Click on this by using the computer mouse. Three stimuli will then appear in three corners of the screen. Choose one of them by clicking on it with the mouse. If you choose the stimulus we have defined as correct, words like "very good", "excellent", and so on will appear on the screen. If you press a wrong stimulus, the word "wrong" will appear on the screen. At the bottom of the screen, the number of correct responses you have made will be counted. During some stages of the experiment, the computer will NOT tell you if your choices are correct or wrong. Please do your best to get everything right. Thank you and good luck!"

No further instructions were given before and after the experiment started.

Trial structure and contingencies. All participants were exposed to the simultaneous protocol to form equivalence classes. Some of them had some simple discrimination training prior to that. In all cases, however, all training and testing were done using trials presented in a matching to sample format that had the following parameters.

Each trial began with the presentation of the sample stimulus in the middle of the screen. Clicking on the sample stimulus by the computer mouse immediately resulted in the presentation of the three comparison stimuli in three of the corners of the screen, while the sample stimulus still remained on the screen. A comparison stimulus was selected by moving the mouse cursor to it and pressing the left button on the mouse. Correct responses in the form of choosing the comparison stimulus according to the experimenter designated classes resulted in the removal of the sample and comparisons stimuli and the presentation of the words *correct*, *very good*, *super*, or *excellent* on the screen. Any other response produced the word *wrong* on the screen. If a programmed consequence was presented after the selection of a comparison, it was displayed in the middle of the screen for 1,000 ms. Termination of the programmed consequences message was followed with a 500 ms inter-trial interval. Between trials, the mouse cursor was returned to the center of the screen.

Equivalence class formation. The simultaneous protocol was used to establish equivalence classes through a three-stage process, each of which consisted of blocks of trials. First, the baseline relations for the equivalence classes were trained in a serialized manner until the achievement of a mastery criterion. Secondly, the baseline relations were maintained in the presence of blocks that contained decreasing proportions of reinforced trials. Third, all of the baseline relations as well as all of the derived symmetrical, transitive, and equivalence relations probes were presented randomly in one emergent relations test block.

Acquisition of baseline relations. The baseline relations were trained in five serialized phases with programmed consequences provided for the selection of comparisons for each trial.

Phase 1 was for the training of AB relations in a block containing nine trials, three from each of the classes. A mastery criterion of at least 90% correct was required to demonstrate acquisition of the relations. Participants repeated each block till the mastery criterion was met. Phases 2, 3 and 4 were the same as phase 1 except that BC, CD, and DE relations were trained in each phase, respectively. An equalization block was used to ensure that each of the baseline relations were trained the same number of times.

Phase 5 involved the inclusion of all the relations trained in the first four blocks: AB+BC+CD+DE. The trials presented in the Phase 5 blocks were A1/**B1**-B2-B3, A2/B1-**B2**-B3, A3/B1-B2-**B3**, B1/**C1-**C2-C3, B2/C1-**C2-**C3, B3/C1-C2-**C3**, C1/**D1-**D2-D3, C2/D1-**D2**-D3, C3/D1-D2-**D3**, D1/**E1-**E2-E3, D2/E1-**E2-**E3, and D3/E1-E2-**E3**. For each of the trial representations, the first stimulus was the sample and the other three were the comparison stimuli whereas the comparison in bold text was the correct comparison. Therefore, in each of the trials, participants were expected to match the samples to the correct comparisons. The comparison stimuli were presented in different positions in the three corners of the screen on a randomized basis. The block contained 36 trials (3 presentations of each of the 12 trial types listed above). The block was repeated until correct comparisons were selected on at least 90% of the trials of each baseline relation in it; the achievement of this mastery criterion defined the acquisition of the baseline relations.

Maintenance of baseline trials. In this phase, participants continued with the training blocks but with reduced programmed consequences across blocks. After the last block of acquisition, the percentage of trials in a block that produced programmed consequences was reduced to 75%, 50%, 25%, and 0% in that order. The mastery criterion for each block was the selection of correct comparisons on at least 90% (33 of 36 trials) of each baseline relation in a block. This programmed reduction of consequences density was conducted to ensure that the baseline relations would be intact even without reinforcement, and the maintenance of baseline relations would not be discriminable from the subsequently presented test blocks, which were also administered without programmed consequences. For each level of programmed consequences, the trials that produced programmed consequences were randomized in a block. The maintenance phase was completed with the mastery level of responding in the last block of 36 baseline trials with no programmed consequences. Table 1 shows a full overview of each of the experimental phases.

Emergent relations tests. The last baseline block, which was presented with no consequences, was followed by an emergent relations test block that contained 180 trials made up of 36 baseline trials; 36 symmetry trials; 54 one-node trials; 36 two-node trials; and 18 three-node trials. All of these trials were randomly presented and without programmed consequences.

Equivalence classes could emerge on either an immediate or delayed basis. To provide for the measurement of delayed emergence, the emergent relations test block was divided into two halves of 90 trials each. The first and second sets were referred to as Test Blocks 1 and 2, respectively. The formation of equivalence classes was defined by the selection of comparisons that were consistent with experimenter-defined classes on at least 90% of the trials in one of the test blocks. Immediate emergence of the classes was said to have occurred when the criterion was reached in the first test block. Thus, the second test block measured the maintenance of the classes. The delayed emergence of the classes was documented when the criterion was not reached in the first test block but was then reached in the second test block. Failure of class formation was documented if sub-mastery performances were obtained in both test blocks.

Simple discrimination training. Before attempting to form equivalence classes, the SIM+SUCC, SIM-only, and SUCC-only conditions were given some forms of discrimination training dependent on their corresponding groups. Participants in the SIM+SUCC condition had both Simultaneous Discrimination training and Successive Discrimination training while the SIM-only and SUCC-only conditions had Simultaneous discrimination training only and Successive discrimination training only respectively.

The simultaneous discrimination training was designed with the help of a software program acquired from the University of North Texas. In the training, the C abstract stimuli were discriminated from other abstract stimuli (X–Z, in bottom panel of Figure 1) by simultaneously presenting the C stimuli together with the others to be discriminated from. The training was done in four phases and through the phases, participants were taught to select C (as S^{D}s) instead of X, Y, and Z (all functioning as S^{Δ}s). Each response also produced a programmed consequence, either "correct" for the selection of the C stimulus or a blank screen for the selection of any other stimulus.

During Phase 1, a block of 30 trials was presented, each trial containing one of the following pairs of stimuli: C1 and X1, C2 and X2, or C3 and X3. Across trials, the location of the stimuli was either on the left or right of the screen and was presented in a randomized sequence. The block was repeated until 10 consecutive correct responses (the selection of the C stimulus) have been made. Phases 2 and 3 were implemented using the same procedures but with the use of the Y1, Y2 and Y3 stimuli in Phase 2, and Z1, Z2 and Z3 stimuli in Phase 3 in place of the three X stimuli. Phase 4 contained a mix of all the trials from the first three phases. C1 was paired with X1, Y1, and Z1; C2 with X2, Y2, and Z2, and C3 with X3, Y3, and Z3. Ten consecutive correct responses out of the 30 trials presented were required as the mastery criterion. Phase 4 was conducted to assess the maintenance of the discrimination between the C stimuli and other stimuli. In each of the 4 phases, if the 30 trials elapsed without the participant making 10 consecutive correct responses, the phase is reintroduced until the criterion is met.

After Phase 4, a test phase was introduced with the presentation of the following pairs of stimuli: C1 vs. P1, R1 or S1; C2 vs. P2, R2 or S2; and C3 vs. P3, R3, or S3 in a two-choice simultaneous discrimination task with the absence of programmed consequences. All trial types were randomly presented in 30 trials and 10 consecutive correct responses were required to master the discrimination.

In the successive discrimination training, a 3-ply multiple schedule was used to establish discriminations among the three C stimuli. When the C1 stimulus was presented on the screen, left clicking on it three times (FR-3) and pressing the END button on the keyboard was followed by ‘‘correct’’ on the screen. Completion of FR-6 and FR-9 before pressing the END button occasioned ‘‘correct’’ programmed consequences in the presence of the C2 and C3 stimuli, respectively. Any other number of responses apart from the experimentally defined ones followed by the END button was followed with the presentation of the programmed consequences word ‘‘wrong’’ on the screen. Ten consecutive correct trials defined mastery and completed this phase of discrimination training.

Results

Acquisition and maintenance of baseline relations. Median trials to acquisition were used to summarize baseline acquisition because a few participants in some groups required many more trials than the rest in a group. As shown in Figure 2, the median speed of acquiring the baseline relations was similar for participants in the SIM+SUCC and PIC conditions. In addition, baseline acquisition speed was similar for participants in the ABS, SIM- only and the SUCC-only conditions. When comparing these to clusters of conditions, the speed of acquiring the baseline relations was faster for the SIM+SUCC and PIC cluster than for the ABS, SIM-only and the SUCC-only cluster; specifically, the participants in the PIC and SIM&SUCC cluster required a median of 270 trials to acquire the baseline relations while the participants in the other cluster required a median of 432 trials to acquire the baseline relations. A U test confirmed the speed of acquisition of the baseline relations as faster for the PIC and SIM+SUCC conditions on one hand and ABS, SIM only and SUCC only conditions on the other hand, $U = -3.86$, $p < .05$, $r = .55$.

Across all conditions, the 14 participants who formed classes required a median of 270 trials to acquire the baseline relations compared to 396 trials for those who did not form classes. A U test showed a significant difference between those who formed equivalence classes and those who did not form classes in terms of their speed of acquiring the baseline relations , $U = -5.292$, $p < .05$, $r = .75$.

In the absence of errors, the maintenance phase would be completed in 144 trials. Of the 50 participants in the experiment, 35 completed the maintenance phase in the minimum number of trials. The remaining 15 participants made a few errors and eventually showed the maintenance of the baseline relations in the absence of programed consequences. The maintenance of the baseline relations was not influenced by experimental condition.

Immediate, delayed, and overall emergence of equivalence classes. Table 2 shows the accuracy of responding in each test block for each participant in each condition. When viewed across all conditions, 11 of the participants showed the mastery level of class consistent responding in both test blocks. These performances indicate the immediate emergence of the classes and their maintenance with test repetition. Nine other participants showed the absence of class indicative performances in the first test block and then mastery in the second test block. These participants, then, showed the delayed emergence of the equivalence classes.

Some of the participants who showed the delayed emergence of the equivalence classes (4380, 4405, 4377, 4379, and 4415) had percentages of correct responses very close to mastery levels in the first test block. The remaining 30 participants showed sub-mastery levels of responding in both test blocks. Even with test repetition, all of these participants failed to form the experimenter defined equivalence classes.

Effects of prior discrimination training on equivalence class formation. This experiment was designed to assess the effects of prior discrimination training on equivalence class formation regardless of the rate of class emergence. Thus, we evaluated the effects of pre class formation discrimination training on the likelihood of class formation by combining yields whether immediate or delayed, which will be referred to as overall yield. These data are illustrated in Figure 3. Each significant outcome in the following description is also indicated with an asterisk at the end of a sentence or relevant phrase. The obtained probabilities associated with chi square tests for each comparative outcome are listed in Table 4.

When no meaningful stimulus was included as a class member (i.e., the ABS condition), only 10% of participants formed classes. The establishment of a simultaneous discriminative function produced the same yield. Thus, the prior acquisition of a simultaneous discriminative function did not enhance the subsequent probability of equivalence class formation.

In contrast, relative to the ABS yield, the establishment of a successive discriminative function produced a 20% increment in likelihood of equivalence class formation. Based on visual inspection, then, the enhancement of class formation was influenced more by the prior establishment of a successive discriminative function than of a simultaneous discrimination function.

Relative to the ABS yield, the combined establishment of successive and simultaneous discriminative functions produced a 60% increment in the likelihood of equivalence class formation (70% vs 10%)*. Further, the 70% yield produced by the prior establishment of simultaneous and successive discriminative functions was greater than the 40% yield produced by summing the yields obtained after simultaneous discrimination training alone (10%) and successive discrimination training alone (30%)*. Thus, the effect of acquiring both discriminative functions together enhanced equivalence class formation in a synergistic manner.

When the PIC condition was used as a reference, class formation was much more likely to occur than when the class consisted of abstract stimuli only (ABS) *, or when the to-be-formed class contained an abstract C stimulus that had previously acquired a simultaneous discriminative function alone (SIM) *, or a successive discriminative function alone (SUCC) *. Finally, very similar yields were produced when the classes contained a meaningful stimulus (PIC) or an abstract C stimulus that had acquired both simultaneous and successive discriminative functions prior to class formation. Thus, the class enhancing effects of including a meaningful stimulus in an equivalence class was matched by the inclusion of an abstract stimulus as a class member as long as it had acquired simultaneous and successive discriminative functions prior to class formation.

Card sorting. The data obtained from the pre and post-class formation sorting test for all participants are presented on the left and right sides of Table 3. Before class formation training, none of the participants sorted the stimuli into any of the experimenter-defined classes. Instead, they produced subject-defined classes that contained different mixes of stimuli from the experimenter-defined classes in sets that contained from 2 to 5 stimuli.

After exposure to the simultaneous protocol, 20 of the 50 participants across all of the conditions sorted the stimuli into the three experimenter-defined classes. The remaining participants sorted the stimuli into clusters that did not correspond to the experimenter-defined classes or into the three experimenter defined classes.

Figure 2 includes the outcomes of the sorting performances along with the results of the emergent relations test data used to document class formation. After the administration of the derived relations tests, all of the participants who formed classes during the derived relations tests also showed maintenance of those classes during the sorting test. Also, participants who did not form classes did not sort the stimuli into the experimenter-defined classes. Thus, there was 100% concordance of performances produced by the class formation test administered using MTS based derived relations trials and the maintenance tests administered using a card sorting format.

Discussion

The present experiment investigated the differential effects of pre-training with simultaneous discriminations and/or successive discrimination on the subsequent formation of 3-node 5-member class where training and testing were administered under the simultaneous protocol. (1) Very few formed classes when the middle nodes as well as the other class members were abstract and meaningless stimuli (ABS). (2) Most participants formed classes when the middle node in the class was a familiar picture (PIC) and the other class members were abstract stimuli. (3) Abstract stimuli that had acquired successive and simultaneous discriminative functions (SIM+SUCC) prior to class formation facilitated class formation that was similar to that found when the middle node was a familiar picture. (4) When either the successive or the simultaneous discriminative function was acquired by an abstract stimulus alone, the successive discrimination training (SUCC-only) produced higher yields than the simultaneous discrimination training (SIM-only). (5) The sum of the two yields produced by the separate discriminations was not as large as that produced by the establishment of both discriminative functions. (6) Finally, a sorting test confirmed the formation of these classes by all the participants that formed classes during the derived relations test.

In general, Results 1, 2, 3, and 6 replicated the findings reported by Fields et al. (2012) and by Travis (2012). The new findings of the present experiment are those mentioned in Results 4 and 5, each of which will be considered below.

Synergistic effects of simultaneous and successive discriminative functions. Travis (2013) explored the effects of pre class formation establishment of SUCC-only and SIM+SUCC discrimination training on equivalence class formation and found that class formation was enhanced more by the prior formation of both types of discriminations than by the prior formation of successive discriminations alone. Further, by the subtraction of one yield from the other, he predicted that the formation of SUCC discriminations alone should enhance class formation more than the formation of simultaneous discriminations. This inference was based on a subtractive theoretical analysis rather than on empirical data. The results of the present experiment confirmed that prediction.

Travis also speculated about the possible additive effects of SIM+SUCC training, but did not draw any definitive conclusions. The present experiment provided a direct answer to this issue. Specifically, the increase in yield produced by the prior establishment of both successive and simultaneous discriminations was greater than that produced by summing the class enhancing effects produced by prior establishment of the successive discrimination alone and the simultaneous discriminations alone. These results then show that the establishment of simultaneous and successive discriminations act in a synergistic manner, where the establishment of one enhances the effect of the other pre class formation training effect: with respect to the class enhancing effects of the two discriminative functions, the whole appears to be greater than the sum of the parts.

Differential effects of simultaneous and successive discriminations. The acquisition of the C-based simultaneous discriminations produced no class enhancement effect. In contrast, the acquisition of the C-based successive discriminations produced a modest enhancement of class formation. The following is a speculative analysis of a factor or mechanism that might account for the superior enhancement effect produced by the pre class formation establishment of the successive discriminations instead of the simultaneous discrimination.

The successive discrimination procedure used in the present experiment required the emission of topographically different responses in the presence of each C stimulus: FR3, FR6, and FR9 responses for the C1, C2 and C3 stimuli, respectively. These responses provided a basis for response coding of the stimuli (Urcuioli, 2013), and might have prompted the emergence of a generalized stimulus coding repertoire. Such a repertoire would then generalize to the emergent relations tests, where the participants would code the sample stimuli in the derived relations test trials, facilitate the selection of a comparison from the same class, and thereby increase the likelihood of class formation.

In contrast, during the formation of a simultaneous discrimination, both stimuli are presented concurrently. The correct response involved the selection of the S^D. Since the same selection based response topography was required even if the S^Δ was chosen, the contingencies of reinforcement were less likely to induce the formation of a generalized coding repertoire. Since it is unlikely that coding behavior was induced, that repertoire was less likely to generalize to and facilitate the solution of the derived relations probes, and thus, enhance the likelihood of equivalence class formation. On the other hand, it is not plausible to argue that nothing had been acquired during the formation of the simultaneous discriminations, because of the synergistic effects of training both the simultaneous and successive discriminations. This admittedly speculative analysis would have to be evaluated with additional research that sought to monitor the presence of coding behavior during the formation of the successive discrimination, the simultaneous discriminations and during the emergent relations tests.

Sidman (1994) argued that, since the two stimuli are presented at the same time in the simultaneous discrimination procedure, the relational characteristics of the stimuli may be easier for the subject to notice than when the stimuli are presented separately. The current study however, reported contradictory findings with a history of successive discrimination training being superior in terms of the likelihood of equivalence class formation than simultaneous discrimination training.

If simultaneous discrimination is easier than successive discrimination (Sidman, 1994), and if both are important prerequisites for the establishment of conditional relations (R. R. Saunders & Green, 1999), then a history of successive discrimination training, which is a more difficult repertoire is far more advantageous to have than a history of simultaneous discrimination training. Thus, having been trained with the more difficult of the prerequisites for forming conditional relations is more favorable than the easier prerequisite. However, since the simultaneous discrimination could have been established by stimulus control based on either selection or rejection, it is possible that most of the participants have learned to respond away from the S^{Δ}, or by rejection, which is a weaker form of stimulus control and one that is bound to lead to failure in the subsequent establishment of conditional relations. The general test for simultaneous discriminations with novel S^{Δ}s, however, suggests that that is not the case. The fact that there was a synergistic effect of training SIM+SUCC provides further evidence that control of behavior had been acquired by the accept relation in simultaneous discriminations.

Potential Effects of Near Misses. When the data in Table 2 are considered, two participants (4371and 4424) did not form classes but responded with increasing accuracy in the second test block than in the first, with performances that approached the criterion used to define class formation. For these participants, the data suggest eventual class formation with additional repetitions of the test block. Were this to have occurred, it would have produced slight increases in the yields obtained in the SUCC+SIM and SIM-only conditions. These increases, however, would not have changed the conclusions that have been drawn from the data as analyzed in the present experiment.

Stimulus control functions of meaningful stimuli. The meaningfulness established by pre-training of otherwise abstract stimuli has been defined by their denotative properties, connotative properties, and more recently by the presumed discriminative properties exerted by these stimuli (e.g., Fields et al., 2012; Tyndall et al., 2004). Specifically meaningful stimuli can serve as S^{D}s in successive discriminations and in simultaneous discriminations, as sample and/or comparison stimuli in identity or arbitrary conditional discriminations, and/or as members of perceptual categories or equivalence classes (Fields et al., 2012; Travis et al., 2014). Many experiments have shown that the inclusion of at least one meaningful stimulus in a set of otherwise meaningless stimuli will facilitate the formation of an equivalence class. Thus, the class enhancing effects of a meaningful stimulus on equivalence class formation might be accounted for in part by some of its inferred acquired stimulus control functions. The results of research presented by Tyndall et al. (2004), Leslie et al. (1993), Fields et al. (2012), and Travis et al. (2014) s support such a perspective. The present research also supports and extends this perspective, suggesting that there are many behavioral stimulus control functions presumably acquired by meaningful stimuli that can account for their ability to enhance the likelihood of forming equivalence classes. Additional research will be needed to determine whether other unexplored stimulus control functions presumably served by meaningful stimuli also contribute to their ability to enhance equivalence class formation.

As noted above, these experiments were conducted using the simultaneous protocol, a procedure that minimizes the likelihood of class formation. Regardless of the implications of the present experiment about the enhancing effects of meaningful stimuli on class formation, the results of the present experiment add to the growing number of variables that enhance the formation of equivalence classes when training and testing are conducted under the simultaneous protocol. The application of these procedures may facilitate learning under these conditions.

Card sorting. None of the participants sorted the stimuli into experimenter-defined classes prior to the experiment. However, after exposure to training and testing, regardless of condition or speed of emergence, participants who formed classes also sorted the stimuli into experimenter-defined classes, and those who did not form classes also did not sort in accord with equivalence. This shows that performances on the card sorting were influenced by the contingencies set in the training and testing for derived relations. These data also show that class based behavior generalized between two trial formats: matching to sample trials during class formation and sorting during post class formation testing. Finally, the post–class formation sorting test documented the maintenance of the classes that had been formed under simultaneous protocol. Similar findings have been reported by Fields et al. (2014).

Summary. The inclusion of a meaningful stimulus in a set of meaningless stimuli enhanced the probability of forming equivalence classes with that set of stimuli. This effect was also produced by the establishment of a simple simultaneous discriminative function in combination with a simple successive discriminative function for one of the meaningless stimulus in a to-be-formed equivalence class. The magnitude of class enhancement was influenced more by the acquisition of a successive discriminative function alone than by the acquisition of a simultaneous discriminative function alone. The acquisition of both functions by a meaningless stimulus had a greater effect than the sum of the acquisition of each of the separate functions. Finally, a post–class formation sorting test documented the maintenance of the classes that had been formed under simultaneous protocol. These results then imply that some portion of the class enhancing effects of meaningful stimuli can be accounted for by the successive and discriminative functions presumably served by meaningful stimuli.

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Table 1. Training and testing sequence

Experimental phases	Trial types	Programmed consequences (%)	Min. # of trials	Criterion
Acquisition of baseline trials				
Trial types presented in a random order				
1. Serialized trials	A1B1, A2B2, A3B3	100	9	9
2. Serialized trials	B1C1, B2C2, B3C3	100	9	9
3. Serialized trials	C1D1, C2D2, C3D3	100	9	9
4. Serialized trials	D1E1, D2E2, D3E3	100	9	9
5. Mixed trials (trials presented randomly)	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	100	36	34
Maintenance : Fading of programmed feedback				
6. Mixed trials (trials presented randomly)	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	75	36	34
7. Mixed trials (trials presented randomly)	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	50	36	34
8. Mixed trials (trials presented randomly)	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	25	36	34
9. Mixed trials (trials presented randomly)	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	0	36	34
Test for derived relations				
All trial types randomly intermixed	Baseline trials			
	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	0	36	34
	Symmetry trials			
	B1A1, B2A2, B3A3, C1B1, C2B2, C3B3 D1C1, D2C2, D3C3, E1D1, E2D2, E3D3	0	36	34
	1 Node trials			
	A1C1, A2C2, A3C3, C1A1, C2A2, C3A3, B1D1, B2D2, B3D3, D1B1, D2B2, D3B3, C1E1, C2E2, C3E3, E1C1, E2C2, E3C3,	0	54	49
	2 Node trials			
	A1D1, A2D2, A3D3, D1A1, D2A2, D3A3 B1E1, B2E2, B3E3, E1B1, E2B2, E3B3	0	36	34
	3 Node trials			
	A1E1, A2E2, A3E3, E1A1, E2A2, E3A3.	0	18	17

Note. The table shows the sequence of training and the test phase, the different trial types, probability of programmed consequences, minimum number of trials and training and test criterion during the conditional discrimination task.

Table 2. Accuracy of selecting class indicative comparison selections for each participant in the two test blocks

Condition	Participant	% correct in test block 1	% correct in test block 2	ECF
ABS	4388	76	93	YES
	4419	70	71	NO
	4407	83	68	NO
	4390	52	57	NO
	4418	46	51	NO
	4387	49	48	NO
	4397	46	46	NO
	4416	44	43	NO
	4399	57	40	NO
	4385	56	32	NO
PIC	4411	97	100	YES
	4410	92	100	YES
	4380	86	100	YES
	4392	96	99	YES
	4405	87	99	YES
	4414	99	98	YES
	4384	99	98	YES
	4413	72	98	YES
	4395	70	73	NO
	4400	64	63	NO
SIM&SUCC	4372	98	100	YES
	4377	82	100	YES
	4374	98	99	YES
	4373	99	98	YES
	4375	93	98	YES
	4379	86	93	YES
	4376	63	90	YES
	4371	61	86	NO
	4370	68	68	NO
	4378	54	54	NO
SIM ONLY	4415	80	96	YES
	4424	70	84	NO
	4404	51	61	NO
	4402	60	48	NO
	4381	52	48	NO
	4401	53	46	NO
	4421	53	46	NO
	4394	48	43	NO
	4393	41	41	NO
	4420	46	39	NO
SUCC ONLY	4389	96	99	YES
	4417	93	97	YES
	4396	78	97	YES
	4391	67	71	NO
	4412	60	62	NO
	4383	57	61	NO
	4422	64	54	NO
	4409	57	47	NO
	4386	40	37	NO
	4408	43	36	NO

Table 3. Pre and post class formation card sorting for all participants

Pre experimental sorting

Group	ECF	ID	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3
ABS	N	4388	3	0	0	1	1	1	1	2	0	0	1	2	0	1	2						
	N	4407	3	1	1	2	2	1	0	2	3												
	N	4390	2	1	0	1	1	0	1	1	0	1	0	1	0	2	0	0	0	2	0	0	2
	N	4419	3	1	1	1	1	3	1	3	1												
	N	4418	3	1	1	1	1	3	1	3	1												
	N	4399	3	1	1	2	2	1	0	2	3												
	N	4387	2	0	0	2	1	0	1	2	1	0	1	2	0	1	2						
	N	4385	2	2	1	2	0	3	1	3	1												
	N	4416	2	1	0	2	1	0	1	1	1	0	2	1	0	0	3						
	N	4397	1	0	2	1	0	2	1	2	0	2	1	0	0	2	1						
PICS	Y	4411	1	1	1	1	1	1	1	1	1	1	0	2	1	0	2						
	Y	4414	3	2	0	1	2	1	1	1	4												
	Y	4384	2	1	1	1	2	1	2	0	1	0	2	2									
	Y	4392	1	1	1	2	0	1	1	1	1	1	1	1	0	2	1						
	Y	4410	3	1	2	1	1	1	1	3	2												
	Y	4380	2	0	1	1	1	1	1	1	0	1	1	0	0	2	1	0	0	2			
	Y	4405	2	1	2	2	3	2	1	1	1												
	N	4413	1	2	1	3	2	3	1	1	1												
	N	4395	4	4	4	1	1	1															
	N	4400	3	3	1	1	1	1	1	1	3												
SIM+SUCC	Y	4372	2	0	1	2	2	0	1	2	1	0	1	1	0	0	2						
	Y	4374	2	1	0	1	0	3	1	2	1	1	1	0	0	1	1						
	Y	4373	1	2	2	2	1	2	2	2	1												
	Y	4375	2	2	1	1	2	2	2	1	2												
	Y	4377	2	0	1	2	1	0	1	0	2	0	2	1	0	2	1						
	N	4379	1	1	0	2	1	1	1	0	1	1	1	1	0	1	1	0	1	1			
	N	4376	2	1	2	2	1	0	1	2	2	0	1	1									
	N	4370	3	1	1	1	3	2	1	1	2												
	N	4371	3	1	0	1	0	2	1	1	1	0	3	2									
	N	4378	3	2	0	1	1	1	1	2	1	0	0	3									
SIM ONLY	N	4415	1	2	2	3	1	1	1	2	2												
	N	4424	2	2	1	3	1	1	0	2	3												
	N	4404	1	0	2	2	1	0	1	0	1	1	1	1	0	3	1						
	N	4402	2	0	0	1	1	0	1	0	1	1	2	1	0	2	3						
	N	4401	1	2	0	2	1	0	1	1	1	1	1	1	0	0	3						
	N	4381	3	1	0	1	0	2	1	1	0	0	2	0	0	1	3						
	N	4421	3	0	1	1	2	3	1	3	1												
	N	4420	3	0	1	1	2	2	1	1	1	0	2	1									
	N	4394	4	1	0	1	1	3	0	3	2												
	N	4393	1	1	1	1	1	1	2	1	0	1	2	0	0	0	3						
SUCC ONLY	Y	4389	2	1	2	2	2	1	1	2	2												
	Y	4417	2	0	0	2	1	0	1	1	0	0	1	1	0	1	2	0	1	2			
	N	4396	1	0	2	1	1	1	1	2	0	1	1	1	1	1	1						
	N	4391	4	1	0	1	3	1	0	1	4												
	N	4412	1	1	0	2	0	0	1	2	0	1	1	2	0	1	1	0	0	2			
	N	4422	1	1	1	2	1	1	2	1	1	0	2	2									
	N	4383	2	1	2	2	1	2	1	3	1												
	N	4409	2	0	0	2	1	0	1	1	1	0	1	1	0	1	1	0	1	2			
	N	4408	2	3	0	3	0	2	0	2	3												
	N	4386	2	1	0	1	0	2	1	2	0	1	1	1	0	1	2						

Post experimental sorting

Group	ECF	ID	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	cls-3	Cls-1	Cls-2	Cls-3
ABS	N	4388	5	0	0	0	5	0	0	0	5												
	N	4407	2	0	0	3	0	0	0	5	0	0	0	5									
	N	4390	3	0	0	2	1	0	0	4	0	0	0	5									
	N	4419	2	1	2	1	3	1	2	1	2												
	N	4418	2	3	0	2	1	2	1	1	3												
	N	4399	2	2	1	1	1	3	2	2	1												
	N	4387	1	0	2	1	0	1	1	2	0	2	0	0	0	2	0	0	1	2			
	N	4385	1	2	2	1	1	2	3	2	1												
	N	4416	2	0	0	1	1	0	2	0	0	0	2	0	0	2	0	0	0	3	0	0	2
	N	4397	2	1	0	1	1	1	2	1	0	0	2	1	0	0	3						
PICS	Y	4411	5	0	0	0	5	0	0	0	5												
	Y	4414	5	0	0	0	5	0	0	0	5												
	Y	4384	5	0	0	0	5	0	0	0	5												
	Y	4392	5	0	0	0	5	0	0	0	5												
	Y	4410	5	0	0	0	5	0	0	0	5												
	Y	4380	5	0	0	0	5	0	0	0	5												
	Y	4405	5	0	0	0	5	0	0	0	5												
	N	4413	5	0	0	0	5	0	0	0	5												
	N	4395	3	1	1	2	2	1	0	2	3												
	N	4400	5	0	0	0	3	2	0	2	3												
SIM+SUCC	Y	4372	5	0	0	0	5	0	0	0	5												
	Y	4374	5	0	0	0	5	0	0	0	5												
	Y	4373	5	0	0	0	5	0	0	0	5												
	Y	4375	5	0	0	0	5	0	0	0	5												
	Y	4377	5	0	0	0	5	0	0	0	5												
	N	4379	5	0	0	0	5	0	0	0	5												
	N	4376	5	0	0	0	5	0	0	0	5												
	N	4370	3	0	0	2	0	0	0	3	0	0	2	0	0	0	5						
	N	4371	1	2	5	4	3	0															
	N	4378	3	0	0	2	1	0	0	3	0	0	1	2	0	0	3						
SIM ONLY	N	4415	5	0	0	0	5	0	0	0	5												
	N	4424	2	2	1	3	2	0	0	1	4												
	N	4404	3	1	0	2	1	0	0	2	3	0	1	2									
	N	4402	2	0	0	1	1	0	2	1	0	0	1	2	0	2	0	0	0	3			
	N	4401	3	0	0	2	0	0	0	2	0	0	1	1	0	2	0	0	0	2	0	0	2
	N	4381	2	0	1	2	0	3	1	3	0	0	2	1									
	N	4421	2	1	1	3	2	1	0	2	3												
	N	4420	3	0	1	1	1	1	1	1	2	0	3	1									
	N	4394	2	1	0	1	1	1	1	1	1	1	1	1	0	1	2						
	N	4393	2	2	1	2	0	3	1	3	1												
SUCC ONLY	Y	4389	5	0	0	0	5	0	0	0	5												
	Y	4417	5	0	0	0	5	0	0	0	5												
	N	4396	5	0	0	0	5	0	0	0	5												
	N	4391	3	2	0	2	3	0	0	0	5												
	N	4412	3	0	1	2	1	0	0	4	0	0	0	4									
	N	4422	2	2	1	3	2	0	0	1	4												
	N	4383	3	1	1	2	3	0	0	1	4												
	N	4409	2	0	0	1	1	0	2	0	0	0	2	0	0	2	0	0	0	5			
	N	4408	2	0	3	2	2	0	1	3	2												
	N	4386	2	0	1	1	0	2	1	1	1	1	1	1	0	3	0						

Note. Rows are grouped by experimental condition, then by success (Y) or failure (N) at equivalence-class formation. Each row is divided into boxes, each of which contains information for one of the subject-defined classes. All boxes have three cells, each of which contains information for experimentally-defined Classes 1, 2, or 3, respectively. The entries in each cell indicate the number of stimuli in each experimenter-defined class that the participant assigned to one subject-defined class. Thus, the number 500 in the three cells in a box would indicate that the five stimuli in Class 1 were clustered into a subject-defined class, while an entry of 302 would indicate a 5-member participant-defined class that contained three stimuli from Class 1, zero stimulus from Class 2, and two stimuli from Class 3. The boxes with gray backgrounds indicate sorting that corresponds to an experimenter-defined class.

Table 4.

P values for chi square tests associated with various group comparisons.

	ABS	SIM	SUCC	SIM+ SUCC	PIC
ABS		.234		***.006***	***.002***
SIM				***.006***	***.002***
SUCC	.132			.074	***.025***
SIM+SUCC					.606
SIM&SUCC				**.007**	

Note. The statistically significant outcomes in the table (valued less than .05) are displayed in the bold and italicized font and correspond to the asterisks (*) included in the description of Figure 3. SIM&SUCC refer to the sum of the yields produced by SIM alone and SUCC alone.

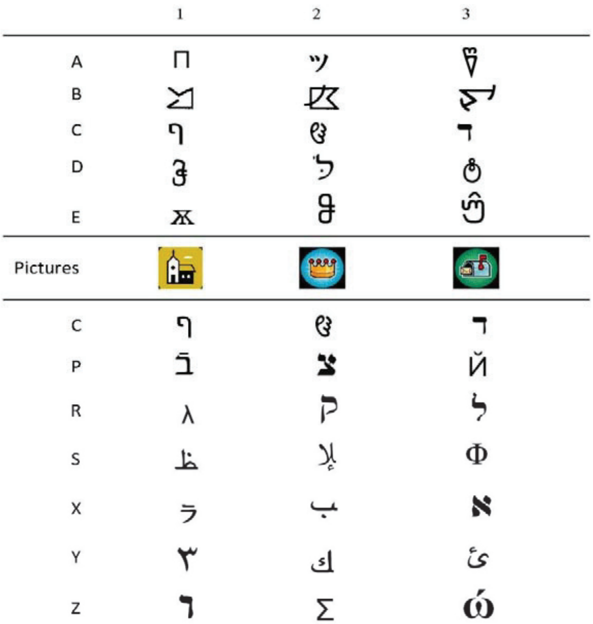

Figure 1. The stimuli used as members of the equivalence classes were abstract and familiar picture-stimuli shown in the two top sections. The bottom section shows the abstract stimuli used during simple discrimination training.

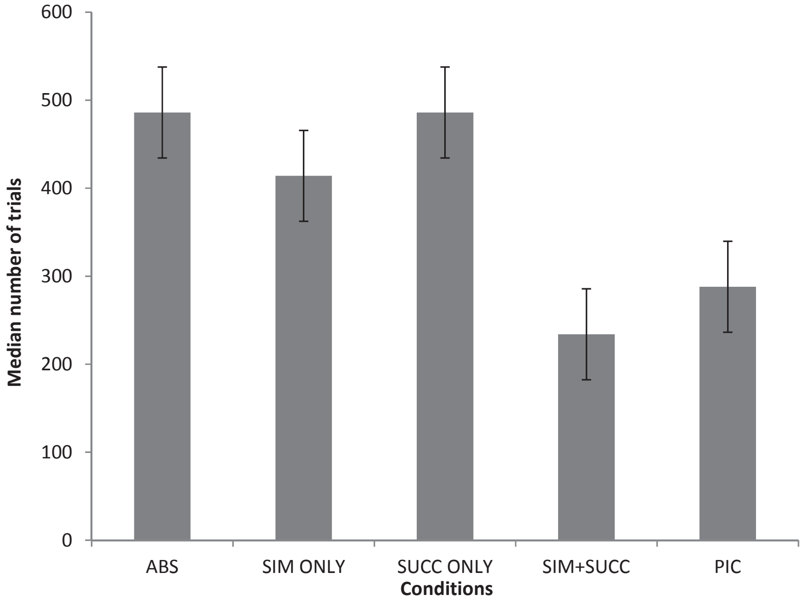

Figure 2. Median trials needed to acquire the baseline relations in the classes.

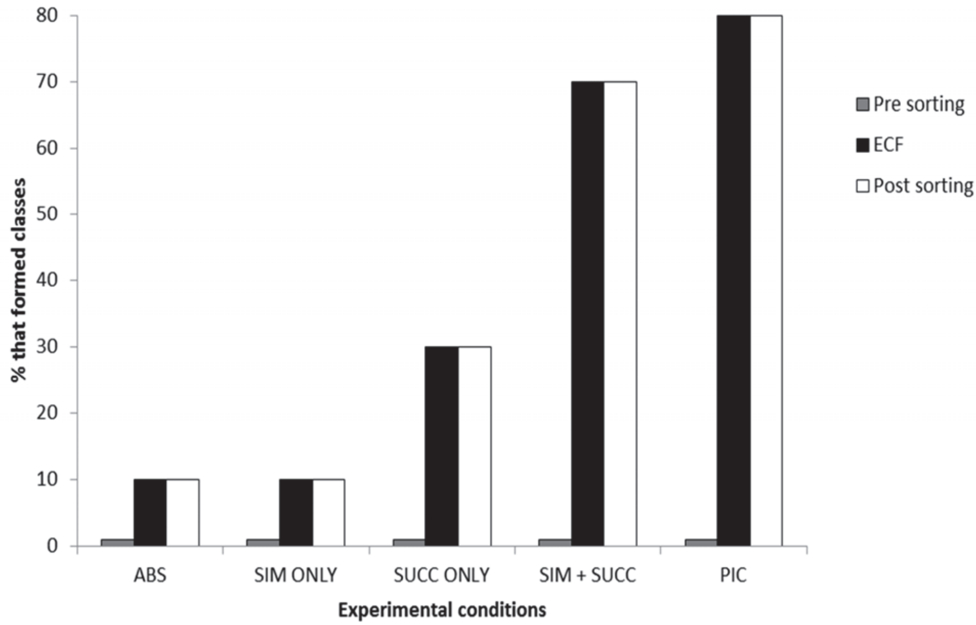

Figure 3. The figure shows data for the pre and post class formation sorting tests, as well as those who formed equivalence classes in the derived relations test used to document equivalence class formation. ECF= Equivalence class formation, ABS= Abstract stimuli, SIM-ONLY= Simultaneous discrimination training only, SUCC-ONLY= Successive discrimination training only, SIM+SUCC= Simultaneous + Successive discrimination training, and PIC= Pictures.

Study 2

Two Discriminative Functions of Meaningful Stimuli That Enhance Equivalence Class Formation

Richard K. Nartey, Erik Arntzen and Lanny Fields

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ORIGINAL ARTICLE

Two Discriminative Functions of Meaningful Stimuli That Enhance Equivalence Class Formation

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Abstract Two experiments explored how order of training, familiar pictures, and abstract stimuli that acquired discriminative functions influenced equivalence class formation. In Experiment 1, three 3-node, 5-member equivalence classes (A→B→C→D→E) were established using a variation of the simultaneous protocol that involved the serialized training of the AB, BC, CD, and DE baseline relations in that order, after which the emergence of all derived relations was tested on a concurrent basis. Classes were formed by 70 % of participants when the A-stimuli were familiar pictures and were members of the first-trained AB relations, while the B-E stimuli were abstract shapes. Classes were formed by 40 % of participants when the E-stimuli were familiar pictures and were members of the last-trained DE relations, while the A-D stimuli were abstract shapes. In two matching conditions, abstract stimuli that had acquired discriminative functions (S^Ds) prior to class formation were substituted for the A and E stimuli, and classes were formed by 20 % of participants in each condition. Further, greater enhancement effects were obtained using pictures than abstract stimuli that have acquired discriminative functions when these stimuli were the A members of the classes, while very little differences in yield were observed when they were the E members of the classes. Thus, likelihood of class formation could have been influenced by the position of a meaningful stimulus or an S^D in the structure of a class (i.e., A or E) and/or their order of introduction during training (first or last). For more than 92 % of the participants (37 of 40), a final sorting task produced the same outcomes as the derived relations tests. Experiment 2 isolated the effects of these variables by the concurrent establishment of the baselines with the A stimuli as pictures or as S^Ds. No participants formed classes in either condition. Thus, class enhancement by a meaningful stimulus depended on its inclusion in the first trained baseline relation and not its placement in the class structure.

Keywords Meaningfulness · Discriminative functions · Serialized · Concurrent · Order of training · Simultaneous protocol · Sorting test

Stimulus equivalence is defined by the emergence of novel conditional discriminations. For instance, after the training of relations such as AB, BC, CD, and DE, the emergence of the untrained relations BA, CB, DC, ED, AC, BD, CE, AD, BE, AE, CA, DB, EC, DA, EB, and EA would demonstrate that the stimuli in the set act as members of an equivalence class (Fields and Verhave 1987; Sidman 1994; Sidman and Tailby 1982). After the training, the untrained relations document the properties of reflexivity, symmetry, transitivity, and the combined properties of symmetry and transitivity (Sidman and Tailby 1982).

Experiments in stimulus equivalence have been conducted with typically developing children and adults (e.g., Arntzen and Lian 2010; Eilifsen and Arntzen 2009), developmentally disabled children and adults (Arntzen et al. 2010a, b); and classes have been formed using different training protocols (Imam 2006), and training structures (Arntzen et al. 2010a, b). Other variables, such as number of nodes (Fields and Verhave 1987) and the instructions prior to training (Arntzen et al. 2008), have also been reported to influence responding in accordance to stimulus equivalence.

There is no conflict of interest to declare concerning the three authors.

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These classes have been formed using stimuli from different sensory modalities, such as tactile (Belanich and Fields 1999), visual (Arntzen and Lian 2010; Fields et al. 2012), olfactory (Annett and Leslie 1995; Fienup and Dixon 2006), auditory (Dube et al. 1993), and gustatory (Hayes et al. 1988). Among the visual stimuli, some were abstract (Sidman et al. 1982) and others were familiar or meaningful pictures (Arntzen and Lian 2010; Fields et al. 2012).

A number of articles have demonstrated that the formation of equivalence classes is enhanced with the inclusion of a meaningful or familiar picture as a member of the potential class (Arntzen 2004; Arntzen and Lian 2010; Arntzen and Nikolaisen 2011; Holth and Arntzen 1998). Arntzen (2004) found that one-node five-member equivalence classes were established by 30 % of participants when all of the stimuli were meaningless, by 100 % when one familiar picture was used in the first trained baseline relation, and by 50 % when the familiar picture was used in the last trained baseline relation. Thus, the inclusion of a meaningful stimulus at different temporal points in training influenced likelihood of equivalence class formation. Arntzen and Lian (2010) established one-node three-member classes by the serial training of the two baseline relations. The classes contained all abstract shapes or two such shapes and one picture. Classes were more likely to form when the picture was used in the first trained baseline rather than the last trained relation. Also, class formation was more likely when nodal stimuli were pictures instead of abstract forms.

Equivalence classes can also contain many nodal stimuli (Fields and Verhave 1987). Thus, Fields et al. (2012) determined whether class enhancement by the inclusion of meaningful stimuli would enhance the formation of multi-nodal classes. In Fields et al. (2012), participants attempted to form three 3-node 5-member equivalence classes by training AB, BC, CD, and DE relations in a serial order. When all of the stimuli were abstract, none of the participants formed classes. In contrast, 80 % of participants formed classes when the A, B, D, and E stimuli were abstract shapes and the C stimuli, which served as nodes, were meaningful pictures. Thus, the formation of large multi-nodal classes was also enhanced by the inclusion of a meaningful stimulus as a class member.

The Fields et al. (2012) experiment also noted that meaningful stimuli can serve a number of stimulus control functions, one of which is discriminative. Thus, Fields et al. (2012) showed that the formation of an equivalence class that consisted of meaningless stimuli was enhanced by the pre class establishment of discriminative function with abstract C stimuli. Enhancement, however, was greater when using the meaningful stimulus than the abstract stimulus that was an S^D. In a systematic replication, Travis, Fields, and Arntzen (in press) showed that the overtraining of the discriminative function increased class enhancement to a level that equaled that produced by meaningful stimuli. That experiment, however, did not explore how class enhancement might have been influenced by many of the parameters that defined the structure of the equivalence classes or the protocols used for training. The following experiments will explore the effects of some of these parameters.

Experiment 1

When establishing a multi-nodal class with a training structure represented as A→B→C→D→E, class enhancement could be influenced by (a) the stimulus in the class that is meaningful or discriminative (e.g., A, B, C, D, or E), and/or (b) the order of establishing the baseline relation that contain the meaningful or discriminative stimuli relative to the other baseline relations that contain abstract stimuli alone. Fields et al. (2012) demonstrated that the use of a meaningful or a discriminative C stimulus enhanced class formation, but did not explore whether a similar effect would occur if these stimuli were used as other class members.

Experiment 1 will explore the formation of 3-node 5-member classes with a training structure represented as A→B→C→D→E. In two conditions, a meaningful stimulus will be used as the A or E class member. In two other conditions, the A or E stimulus will be an abstract shape: A meaningless stimulus that has acquired a discriminative function prior to class formation. Finding no differences in yields across these manipulations would indicate the constancy of the class-enhancing effects of the meaningful or abstract stimuli that had acquired discriminative functions prior to class formation. Finding differential effects of the locational parameter would indicate that the class-enhancing effects of meaningful or discriminative stimuli are influenced by the structural parameters of the classes being formed.

Method

Participants

Forty university students (21 males and 19 females) between the ages of 18 and 36 years voluntarily participated in the study. The average age was 23 years (*SD*=4.1). None of them had any prior knowledge of stimulus equivalence research and methodology. Five other participants who started the experiment either quit or were dismissed because they did not acquire the baseline relations after 2 hours of training.

Informed Consent

Upon entering the experimental room, each participant was asked to be seated and to read the consent form given out by the experimenter. Some of the major highlights of the consent form were that they were about to participate in an experiment in the field of behavior analysis, and that it would last approximately one and half hours. Participants were also informed that they are required to respond to certain stimuli on the screen of a computer with mouse clicks, that there are no known harmful effects of participating in the study, and that they were free to withdraw from the experiment at any time without any negative consequences. The experiment began after the participant had signed the consent form.

Apparatus

Setting The experiments were conducted in the lab room of the Department of Psychology at the University of Ghana, Legon. The lab room measures approximately 5 m square and is furnished with tables and chairs.

Hardware The experiments were conducted on an HP Compaq nc6320 laptop computer that used an 1828 MHz Intel Centrino® processor, and had a screen with a 16.8 in diagonal length and with a 16×9 horizontal-to-vertical ratio. An external mouse was used by participants to control the position of the cursor throughout the experiment.

Software All sessions for training and testing of conditional discriminations for all participants were conducted with a software program version 3.12 made by Psych Fusion Software in collaboration with the second author. The software controlled the presentation of all stimuli and also made recordings of data, including the trial number, number of training trials, whether or not participant chose the correct/incorrect comparison, and whether or not programmed consequences was delivered on each trial. The software also provided a summary of baseline or direct trained trials, symmetry trials, transitivity trials, and equivalence trials as well as the duration of the experiment.

For participants in the A-as-S^D and E-as-S^D conditions, however, an initial exposure to some of the stimuli with the help of two different software programs acquired from the University of North Texas, and University of Sao Paulo in Brazil was done, in an attempt to help establish some of the stimuli as discriminative stimuli (S^D) prior to the simultaneous protocol.

Stimuli The stimuli used as members of equivalence classes were the abstract pictures and the familiar pictures illustrated in the upper panel of Fig. 1. The stimuli used for simple discrimination training were the unfamiliar Hebrew and Arabic letters shown in the bottom section of Fig. 1. The abstract stimuli were displayed in black and the picture stimuli in colours, with both on white backgrounds. They were presented on a computer screen in 9.4 cm x 3.4 cm areas. In addition, each of the 15 abstract stimuli and the pictures to be used in the experiment was presented on a separate plastic-laminated card that was 3.8 cm square.

Design

Participants were assigned on a block randomized basis to one of four different conditions; (1) Meaningful A stimulus (A-as-PIC); (2) Meaningful E stimulus (E-as-PIC); (3) Acquired Discriminative Function of A- abstract stimulus (A-as-S^D); and (4) Acquired Discriminative Function of E abstract stimulus (E-as-S^D). Each participant attempted to form three 3-node 5-member equivalence classes in a linear series training structure represented as A→B→C→D→E. For participants in the Meaningful A stimulus condition, attempts were made to form equivalence classes that consisted of an A stimulus that was meaningful, and B, C, D, and E stimuli that were abstract shapes. Those in the E-as-PIC condition attempted to form equivalence classes that consisted of A, B, C, D stimuli that were abstract shapes, and an E stimulus that was a meaningful picture. For participants in the A-as-S^D and E-as-S^D conditions, attempts were made to form equivalence classes that consisted of abstract stimuli only, after the A or E stimuli, for the A-as-S^D or E-as-S^D conditions respectively, have been established as S^Ds.

Procedure

Categorization of Stimuli: Card Sorting After participants had signed the informed consent, they remained seated and were given 15 plastic-laminated cards that consisted of the stimuli sets to be used in one of the Conditions (15 abstract for participants in the A-as-S^D and E-as-S^D conditions; and 12 abstract and 3 pictures for participants in the A-as-PIC and E-as-PIC conditions), and were asked by the experimenter to "put them into groups". After the experiment, the categorization task was once again administered to the participants. The resulting data provided a pre-class and post-class formation measure of the sorting of the stimuli into experimenter-defined classes.

Conditional Discrimination Training After the initial categorization task, participants remained seated facing the computer monitor and were presented with the following instructions on the computer screen:

> "In a moment a stimulus will appear in the middle of the screen. Click on this by using the computer mouse. Three stimuli will then appear in three corners of the screen. Choose one of them by clicking on it with the mouse. If you choose the stimulus we have defined as correct, words like "very good", "excellent", and so on will appear on the screen. If you press a wrong stimulus, the word "wrong" will appear on the screen. At the bottom of the screen, the number of correct responses you have made will be counted. During some stages of the experiment, the computer will NOT tell you if your

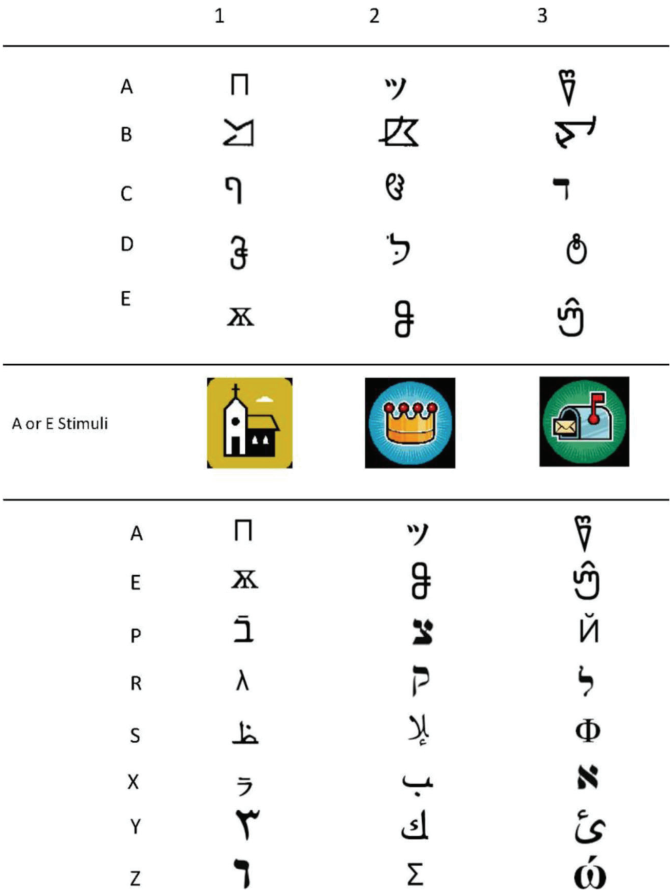

Fig. 1 The stimuli used as members of the equivalence classes were abstract and familiar picture stimuli, as shown in the two top sections. The bottom section shows the abstract stimuli used during simple discrimination training

choices are correct or wrong. However, based on what you have learned so far, you can get all of the tasks correct. Please do your best to get everything right. Thank you and good luck!"

After this, no further instructions were given before and after the experiment started.

After simple discrimination training (see below), when used, participants attempted to form equivalence classes under the simultaneous protocol. All training and testing were done in blocks of trials. First, the baseline relations were trained in a serialized manner before all of them, and all derived symmetrical, transitive, and equivalence relations were presented randomly in the same test block. See Table 1 for a full overview of each of the experimental phases.

Each trial began with the presentation of the sample stimulus in the middle of the screen. Responding to the sample stimulus by a mouse click on it was immediately followed by the presentation of the three comparison stimuli at three of the corners of the screen, while the sample stimulus still remained on the screen. A comparison was selected by moving the mouse cursor to it and pressing the left button on the mouse. Correct responses, in the form of choosing the correct comparison stimulus according to the experimenter designated classes produced the words *correct*, *very good*, *super*, or *excellent* on the screen. Any other response produced the word *wrong* on the screen. If a programmed consequence was presented after the selection of a comparison, it was displayed in the middle of the screen for 1,000 ms. Termination of the programmed consequences message was followed with a 500-ms inter-trial interval. Between trials, the mouse cursor was returned to the center of the screen.

Acquisition of Baseline Relations All baseline relations were trained in five serialized phases with programmed consequences provided for the selection of comparisons for each

Table 1 Sequence of training and testing

Experimental phases	Trial types	Programmed consequences	Min. # of trials	Criterion
Acquisition of baseline trials				
Trial types presented in a random order				
1. Serialized trials	A1B1, A2B2, A3B3	100 %	9	9
2. Serialized trials	B1C1, B2C2, B3C3	100 %	9	9
3. Serialized trials	C1D1, C2D2, C3D3	100 %	9	9
4. Serialized trials	D1E1, D2E2, D3E3	100 %	9	9
5. Mixed trials (trials presented randomly)	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	100 %	36	34
Maintenance : Fading of programmed feedback				
6. Mixed trials (trials presented randomly)	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	75 %	36	34
7. Mixed trials (trials presented randomly)	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	50 %	36	34
8. Mixed trials (trials presented randomly)	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	25 %	36	34
9. Mixed trials (trials presented randomly)	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	0 %	36	34
Test for derived relations				
All trial types randomly intermixed	Baseline trials			
	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	0 %	36	34
	Symmetry trials			
	B1A1, B2A2, B3A3, C1B1, C2B2, C3B3 D1C1, D2C2, D3C3, E1D1, E2D2, E3D3	0 %	36	34
	1 Node trials			
	A1C1, A2C2, A3C3, C1A1, C2A2, C3A3 B1D1, B2D2, B3D3, D1B1, D2B2, D3B3, C1E1, C2E2, C3E3, E1C1, E2C2, E3C3,	0 %	54	49
	2 Node trials			
	A1D1, A2D2, A3D3, D1A1, D2A2, D3A3 B1E1, B2E2, B3E3, E1B1, E2B2, E3B3	0 %	36	34
	3 Node trials			
	A1E1, A2E2, A3E3, E1A1, E2A2, E3A3.	0 %	18	17

Note. The table shows the sequence of training and the test phase, the different trial types, probability of programmed consequences, minimum number of trials and training and test criterion during the conditional discrimination task

trial. Phase 1 was for the training of AB relations in blocks containing nine trials, three each of the three classes. Participants repeated each block till the mastery criterion was met. The mastery criterion of at least 90 % correct in a block was required for the training of each relation. A total number of nine correct trials out of nine trials were therefore required to proceed to the training of the next relation in the first four training phases. Phases 2, 3, and 4 were the same as Phase 1, except that BC, CD, and DE relations were trained in each phase, respectively. An equalization block feature was used to ensure that each of the baseline relations were trained the same number of times.

Phase 5 involved the inclusion of all the relations trained in the first four blocks: AB+BC+CD+DE. The trials presented in the Phase 5 block were **A1**/B1-B2-B3, **A2**/B1B2B3, **A3**/B1-B2-B3, **B1**/C1-C2-C3, **B2**/C1-C2-C3, **B3**/C1-C2-C3, **C1**/D1-D2-D3, **C2**/D1-D2-D3, **C3**/D1-D2-D3, **D1**/E1-E2-E3, **D2**/E1-E2-E3, and **D3**/E1-E2-E3. For each of the trial representation, the first stimulus is the sample (in bold) and the other three are the comparison stimuli, whereas the underlined comparison is the correct comparison. Therefore, in each of the trials, participants were expected to match the samples to the correct comparisons. The comparison stimuli were presented in different positions in the three corners of the screen on a randomized basis. Phase 5 contained 36 trials (three presentations of each of the 12 trial types listed above). The block was repeated until correct comparisons were selected on at least 90 % of the trials of each baseline relation in a block (the mastery criterion), which defined the acquisition of the baseline relations.

Maintenance of Baseline Trials The percentage of trials in a block that produced programmed consequences after the last acquisition of baseline trials phase was reduced to 75 %, 50 %, 25 %, and 0 % in that order. For each level of programmed consequences, the trials that produced programmed consequences were randomized in a block. Each block was repeated until correct comparisons were selected on at least 90 % of the trials of each baseline relation in the block (the mastery criterion). The maintenance phase was completed with the mastery level of responding occurring in the last block of 36 baseline trials with no programmed consequences. This gradual cross-phase reduction of reinforcement density was necessary to ensure that the baseline relations were still intact even without reinforcement as the participant entered the derived relations test block.

Derived Relations Test Blocks The last block with no programmed consequences was followed by a derived relations test block of 180 trials that included 36 baseline trials, 36 symmetry trials, 54 one-node trials, 36 two-node trials; and 18 three-node trials. All of the trials were randomly presented and without programmed consequences.

For analytic purposes, the test block was divided into two halves, each containing 90 trials. The first and second sets of 90 trials are referred to as Test Blocks 1 and 2, respectively. The formation of equivalence classes was defined by the selection of comparisons that were consistent with experimenter-defined classes on at least 90 % of the trials in either test block. Immediate emergence of the classes was documented if the criterion was reached in the first test block. When that occurred, the second block measured the maintenance of the classes. The delayed emergence of the classes was documented if the criterion was not reached in the first block and was then achieved in the second block. Failure of class formation was documented if sub-mastery performances were obtained in both test blocks. Finally, mastery in the first block and sub-mastery in the second block indicated the immediate emergence of the classes, followed by a breakdown of the classes or interference with class-based control of behavior.

Simple Discrimination Training Before the exposure to the training of baseline relations and the subsequent test for emergent relations, the participants in the A-as-S^D and E-as-S^D conditions were given two different forms of discrimination training, called Simultaneous Discrimination training and Successive Discrimination training, respectively. The simultaneous discrimination training was designed with the help of a software program acquired from the University of North Texas. In the training, the A abstract or E abstract in the A-as-S^D and the E as S^D conditions, respectively, were discriminated from other abstract stimuli (X–Z, in bottom panel of Fig. 1) by simultaneously presenting the A or E stimuli together with the others to be discriminated from. The training was done in four phases and through the phases, participants were taught to select A for the A-as-S^D condition and E for the E-as-S^D condition (as S^Ds) instead of X, Y, and Z (all functioning as S^Δs). Each response also produced a programmed consequence, either "correct" for the selection of the A or E stimulus, or a blank screen for the selection of any other stimulus.

During Phase 1, a block of 30 trials was presented, each trial containing one of the following pairs of stimuli: A1/E1and X1, A2/E2 and X2, or A3/E3 and X3. Across trials, the location of the stimuli was either on the left or right of the screen and was presented in a randomized sequence. The block was repeated until ten consecutive correct responses (the selection of the A or E stimulus depending on the condition) were made. Phases 2 and 3 were implemented using the same procedures as that used in Phase 1, but with the replacement of the X stimuli with Y1, Y2 and Y3 stimuli in Phase 2, and Z1, Z2 and Z3 stimuli in Phase 3. Phase 4 contained a mix of all the trials from the first three phases. A1/E1, depending on the condition was paired with X1, Y1, and Z1; A2/E2 with X2, Y2, and Z2, and A3/E3 with X3, Y3, and Z3. Ten consecutive correct responses out of the 30 trials presented were required as the mastery criterion. Phase 4 was conducted to assess the maintenance of the discrimination between the A/E stimuli and other stimuli. In each of the four phases, if the 30 trials elapsed without the participant making ten consecutive correct responses, the phase is reintroduced until the criterion was met.

After Phase 4, a test phase was introduced with the presentation of the following pairs of stimuli: A1/E1, depending on the condition was paired with P1, R1 or S1; A2/E2 with P2, R2 or S2; and A3/E3 with P3, R3, or S3 in a two-choice simultaneous discrimination task in the absence of programmed consequences. All trial types were randomly presented in 30 trials, and ten consecutive correct responses were required to master the discrimination.

Participants were then introduced to the successive discrimination training. Here, a three-ply multiple schedule was used to establish discriminations among the three A (A1, A2, and A3) or E (E1, E2, and E3) stimuli, depending on the condition. When the A1 or E1 stimulus was presented on the screen, left clicking on it three times (FR-3) and pressing the END button on the keyboard was followed by "correct" on the screen. For A2 or E2, the completion of an FR-6 before pressing the END button occasioned "correct" programmed consequences, while in the presence of A3 or E3 stimuli, left clicking on the stimulus nine times (FR-9) and pressing the END button on the keyboard occasioned "correct" programmed consequences. Any other number of responses apart from the experimentally defined ones followed by the END button was followed with the presentation of the programmed consequence "wrong" on the screen. Ten consecutive correct trials defined mastery and completed this phase of discrimination training.

Results and Discussion

Baseline Acquisition Figure 2 shows how acquisition speed of the baseline relations (the inverse of number of trials to reach the mastery criterion) was influenced by the order of training, location of the pictures or S^Ds in the class structure, and for those participants who did and did not form classes. For participants who formed equivalence classes (YES), fewer trials were needed to learn all of the baseline relations when the pictures or abstract stimuli that functioned as S^Ds were used as the A stimuli instead of the E stimuli. Thus, for participants who formed equivalence classes, the speed of baseline acquisition was influenced by the order of training and/or the structural location of the meaningful or the discriminative stimuli in the training structure.

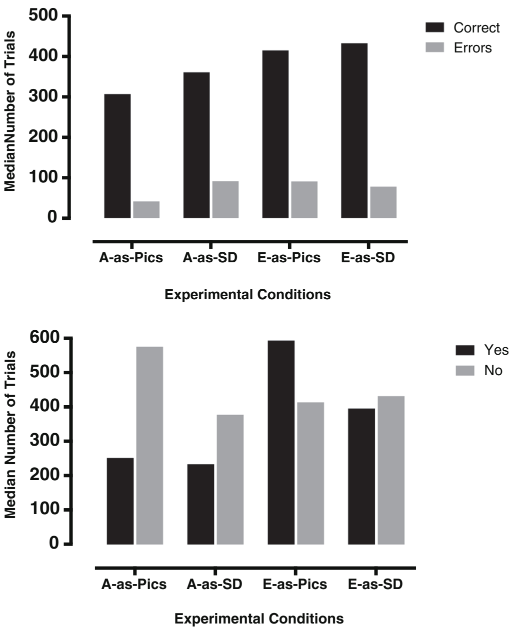

Fig. 2 The upper panel shows median of the total number of correct responses and errors in the acquistion phase. The lower panel shows median of number of trials for participants who respond in accordance with equivalence formation and those who did not across different experimental conditions. Yes=Participants who did form equivelance classes and No=Participants who did not form equivalence classes

For participants who did not form equivalence classes (NO), acquisition of baseline relations varied somewhat across conditions, but in an unsystematic manner. Thus, the speed of acquiring the baseline relations was not influenced by the order of training and/or the structural location of these stimuli in the training structure.

Maintenance of Baseline Relations A minimum of 144 trials was required to complete the maintenance phase without making any errors. Of the 40 participants in the experiment, 29 completed the maintenance phase in the minimum number of trials, while the remaining 11 completed the phase in an average of 272 trials. These results indicate that the baseline relations were resistant to disruption with the systematic reduction of programmed consequences scheduled in the present experiment.

Equivalence Class Formation Equivalence classes can emerge on an immediate or delayed basis. Table 2 shows the percentages of participants in each condition who did and did not form all three stimulus equivalence classes, regardless of immediate or delayed emergence. Across all conditions, 11 of the 15 participants who formed classed did so on an immediate basis (mastery in the first test block), followed by the maintenance of class consistent responding in the second test block. The four remaining participants (4515, 4507, 4543, and 4536) did not respond at the mastery level in the first test block, but then responded in a class consistent manner on at least 90 % of the trials in the second half of the test block, and thus showed the delayed emergence of the three equivalence classes. However, for these participants, the first test block produced rather high levels of accuracy, which suggest that the emergence of the classes could well have occurred during the first test block. Overall yields were therefore most representative of the effects of the different conditions on the likelihood of class formation. The remaining participants did not respond at mastery in either test block.

Figure 3 shows the percentage of participants in each condition who formed all three stimulus equivalence classes, regardless of immediate or delayed emergence. When one class member was a picture, equivalence classes were formed by 70 % of the participants when it was either the A-stimuli were pictures (A-as-PIC), and by 40 % of the participants where the E-stimuli were pictures (E-as-PIC). When one class member was an abstract shape that had acquired a discriminative function, equivalence classes were formed by 20 % of the participants when it was either the A- or E-stimuli (A-as-S^D or E-as-S^D). Comparing the effects of training with

Table 2 Percentage of participants who formed classes

Condition	Participant	% Correct in Test Block 1	% Correct in Test Block 2
A-as-PIC	4504	**100**	**100**
A-as-PIC	4550	**100**	**100**
A-as-PIC	4506	**99**	**99**
A-as-PIC	4538	**97**	**94**
A-as-PIC	4537	**94**	**100**
A-as-PIC	4534	**94**	**100**
A-as-PIC	4524	**92**	**98**
A-as-PIC	4502	76	67
A-as-PIC	4531	57	61
A-as-PIC	4509	53	34
A-as-SD	4523	**99**	**97**
A-as-SD	4513	**91**	**100**
A-as-SD	4517	70	71
A-as-SD	4532	70	69
A-as-SD	4541	66	62
A-as-SD	4511	58	60
A-as-SD	4530	56	53
A-as-SD	4528	56	49
A-as-SD	4540	48	49
A-as-SD	4505	40	41
E-as-PIC	4501	**90**	**97**
E-as-PIC	4515	87	**100**
E-as-PIC	4507	86	**99**
E-as-PIC	4543	82	**98**
E-as-PIC	4527	78	67
E-as-PIC	4519	77	77
E-as-PIC	4535	67	82
E-as-PIC	4526	60	60
E-as-PIC	4512	58	33
E-as-PIC	4542	57	59
E-as-SD	4525	**98**	**99**
E-as-SD	4536	87	**99**
E-as-SD	4508	76	56
E-as-SD	4539	73	79
E-as-SD	4533	73	72
E-as-SD	4522	60	53
E-as-SD	4529	59	54
E-as-SD	4520	57	74
E-as-SD	4521	56	61
E-as-SD	4514	47	40

Note. The table shows the percentage of participants who formed classes in each of the two test blocks. Performances of 90 % correct or more indicate formation of classes and are written in bold in the table

pictures vs. abstract S^Ds first, yields were greater with the pictures than with the S^Ds. The same outcome was observed

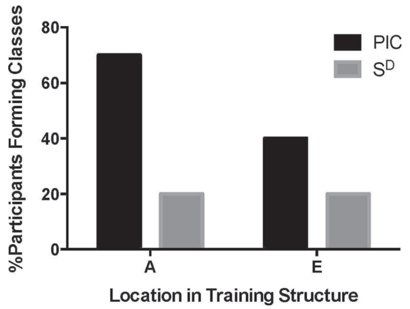

Fig. 3 The percentage of participants that formed equivalence classes in each of the experimental conditions in Experiment 1

when training with these stimuli was conducted last. When compared to the A stimulus as an S^D, training with the A stimulus as pictures resulted in higher proportions of participants responding in accordance with equivalence during the derived relations tests.

To summarize, the class-enhancing effect was an interactive function of stimulus type (pictures and discriminative stimuli), the order of establishing baseline relations that included these stimuli in the first and last trained relations (a dynamic protocol effect), and/or the inclusion of these stimuli in different locations in the structures of the equivalence classes (a static structural effect). Stimulus type alone was not fully predictive of class enhancement.

Sorting Test Performances Table 3 shows data from the pre-class and post-class formation card sorting tasks with the data for each participant in a separate row. Before training, no participant sorted the stimuli in any of the experimenter-defined class. After exposure to the class formation procedure, 37 of the 40 participants in Experiment 1 (except participants 4543, 4524, and 4535) sorted the stimuli into sets that corresponded to their performances in the last derived relations test block. For 92 % of the participants, then, the yields computed from the sorting data corresponded exactly to the outcomes produced from the derived relations tests. These results also showed the generalization of class membership to a test format that differed from that used to document class formation.

Summary Prior research showed that the inclusion of a meaningful stimulus or a meaningless stimulus that has acquired a discriminative function enhanced the formation of an equivalence class that contained either of these stimuli. The present experiment demonstrated that the inclusion of such a stimulus does not always enhance the formation of an equivalence class. Rather, the class-enhancing function of either of these stimuli is modulated by the order in which either of these

Table 3 The pre and post class formation card sorting data for all the participants in experiment 1

			Pre experimental sorting																				
Group	ECF	ID	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3
A-as-Pic	Y	4504	1	1	1	0	0	1	4	4	3												
	Y	4550	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1			
	Y	4506	1	1	1	1	1	1	1	0	2	1	1	1	1	2	0						
	Y	4538	1	1	1	3	2	2	1	2	2												
	Y	4537	1	1	1	2	1	0	2	2	2	0	1	2									
	Y	4534	3	1	2	1	2	2	1	2	1												
	Y	4524	1	1	1	2	3	3	2	1	1												
A-as-Pic	N	4502	2	2	1	1	2	2	2	1	2												
	N	4531	1	1	0	1	1	0	1	1	0	2	0	1	0	2	2	0	0	2			
	N	4509	1	1	1	1	2	0	2	1	0	1	1	1	0	0	3						
A-as-S^D	Y	4523	3	1	0	2	3	2	0	1	3												
	Y	4513	2	0	0	1	0	1	1	1	0	1	0	1	0	2	1	0	1	1	0	1	1
A-as-S^D	N	4517	3	0	1	2	2	1	0	2	2	0	1	1									
	N	4532	2	1	1	1	2	1	1	2	2	1	0	1									
	N	4541	3	1	0	1	0	1	1	1	0	0	2	0	0	1	2	0	0	2			
	N	4511	2	1	0	1	0	2	1	2	0	1	0	2	0	2	1						
	N	4530	1	0	2	1	2	0	3	0	0	0	2	1	0	1	2						
	N	4528	3	1	0	2	2	3	0	2	2												
	N	4540	3	1	1	2	1	2	0	3	2												
	N	4505	5	5	5																		
E-as-Pic	Y	4501	3	0	2	1	3	1	1	2	2												
	Yd	4515	3	0	2	1	0	0	1	1	1	0	1	0	0	1	1	0	1	1	0	1	0
	Yd	4507	2	3	0	2	1	3	1	1	2												
	Yd	4543	3	0	1	1	2	0	1	1	1	0	2	1	0	0	2						
E-as-Pic	N	4527	1	1	1	3	0	1	1	3	1	0	1	2									
	N	4519	3	1	0	1	0	2	0	2	1	0	1	1	1	1	1						
	N	4535	3	1	1	1	3	3	1	1	1												
	N	4526	4	2	0	1	3	2	0	0	3												
	N	4512	3	0	2	2	2	1	0	3	2												
	N	4542	4	4	4	1	1	1															
E-as-S^D	Y	4525	2	0	2	1	1	2	1	2	1	1	2	0									
	Yd	4536	3	1	2	1	0	1	1	2	2	0	2	0									
E-as-S^D	N	4508	1	1	0	1	2	2	1	0	1	1	0	1	1	1	0	0	1	1			
	N	4539	2	1	0	1	2	2	1	2	1	1	0	2									
	N	4533	3	2	3	2	3	2															
	N	4522	2	0	1	3	0	0	0	3	0	0	2	1	0	0	3						
	N	4529	2	1	2	1	3	1	2	1	2												
	N	4520	2	0	2	2	0	2	1	2	0	0	3	1									
	N	4521	2	1	1	2	1	2	1	1	1	0	2	1									
	N	4514	1	3	1	2	1	2	2	1	2												

			Post experimental sorting																				
Group	ECF	ID	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	cls-3	Cls-1	Cls-2	Cls-3
A-as-Pic	Y	4504	5	0	0	0	5	0	0	0	5												
	Y	4550	5	0	0	0	5	0	0	0	5												
	Y	4506	5	0	0	0	5	0	0	0	5												
	Y	4538	5	0	0	0	5	0	0	0	5												
	Y	4537	5	0	0	0	5	0	0	0	5												
	Y	4534	5	0	0	0	5	0	0	0	5												
	Y	4524	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1						
A-as-Pic	N	4502	2	3	0	3	2	0	0	0	5												
	N	4531	4	0	0	0	2	0	0	3	0	1	0	5									
	N	4509	5	0	0	0	3	2	0	2	3												
A-as-S^D	Y	4523	5	0	0	0	5	0	0	0	5												
	Y	4513	5	0	0	0	5	0	0	0	5												
A-as-S^D	N	4517	3	1	0	2	4	0	0	0	5												
	N	4532	2	1	0	3	1	0	0	3	1	0	0	4									
	N	4541	3	0	2	0	5	0	2	0	3												
	N	4511	2	0	1	1	1	1	1	1	1	1	1	1	0	2	1						
	N	4530	2	0	1	3	0	0	0	3	0	0	2	1	0	0	3						
	N	4528	2	0	0	3	0	0	0	2	1	0	3	0	0	0	4						
	N	4540	2	2	1	2	2	1	1	1	3												
	N	4505	2	0	0	2	0	0	1	2	0	0	2	0	0	1	1	0	0	4			
E-as-Pic	Y	4501	5	0	0	0	5	0	0	0	5												
	Yd	4515	5	0	0	0	5	0	0	0	5												
	Yd	4507	5	0	0	0	5	0	0	0	5												
	Yd	4543	3	0	0	2	0	0	0	5	0	0	0	3	0	0	2						
E-as-Pic	N	4527	2	2	1	3	2	0	0	1	4												
	N	4519	2	3	0	3	2	0	0	0	5												
	N	4535	5	0	0	0	5	0	0	0	5												
	N	4526	4	1	0	1	0	3	0	4	2												
	N	4512	1	1	2	3	0	1	1	1	1	0	3	1									
	N	4542	2	0	0	1	1	1	2	0	0	0	2	0	0	2	0	0	0	2	0	0	2
E-as-S^D	Y	4525	5	0	0	0	5	0	0	0	5												
	Yd	4536	5	0	0	0	5	0	0	0	5												
E-as-S^D	N	4508	2	1	0	1	1	0	2	0	0	0	3	1	0	0	4						
	N	4539	4	1	0	1	4	0	0	0	5												
	N	4533	5	0	0	0	2	0	0	2	3	0	1	2									
	N	4522	1	0	1	2	0	0	2	0	0	0	2	0	0	3	0	0	0	2	0	0	2
	N	4529	1	2	1	1	1	1	1	1	1	2	1	2									
	N	4520	5	1	0	0	4	1	0	0	4												
	N	4521	2	0	0	2	2	0	1	0	2	0	3	3									
	N	4514	4	0	1	1	3	1	0	2	3												

Note. Each row presents data for a separate participant. Each row is divided into boxes that correspond to the classes into which the participant sorted the cards. All boxes have three cells, each of which shows the number of cards from the experimenter-defined classes that were sorted into one participant-defined class. Thus, the number 500 in the three cells in a box would indicate that the five stimuli in Class 1 were clustered into a subject-defined class, and an entry of 213 would indicate a six-member participant-defined class that contained two stimuli from Class 1, one stimulus from Class 2, and three stimuli from Class 3. The boxes with gray backgrounds indicate sorting that corresponds to an experimenter-defined class. In the second column, Y= immediate emergence of the three classes during the derived relations test, Yd=the delayed emergence of the three classes during the derived relations test, and N=failed emergence of all three classes during the derived relations test

stimuli is introduced during the serial training of the baseline relations that are the prerequisite of an equivalence class and/or the location of those stimuli in the training structure of the class.

Experiment 2

In Experiment 1, the baseline relations were trained in a serial order, with the AB and DE relations trained first and last, respectively. In different conditions, the pictures were used as the A or the E stimuli. Any difference in outcome could have to be due to the order of introducing the picture in the training and/or their location in the training structure. Experiment 2 was designed to isolate the effect of training order on the class enhancement effect. This was done by the concurrent training of all of the baseline relations.

If the order of introduction is the variable responsible for class enhancement, the concurrent training of all of the baseline relations should eliminate a presumed effect of order of introduction and result in very low likelihoods of class formation when the A stimuli are pictures or abstract shapes that were functioning as S^Ds. If location in the class is the controlling variable, high yields should be obtained with pictures as the A stimuli and somewhat lower yields should be obtained when the A stimuli are S^Ds. Indeed, the yields should be similar to those obtained in comparable conditions in Experiment 1.

Method

Participants

Twenty university students, 12 males and 8 females between the ages of 20 and 35 years voluntarily participated in this experiment. Their average age was 20.8 years (*SD*=0.84). All were naïve in terms of knowledge of stimulus equivalence research and methodology. They were assigned in a block-randomized manner to two conditions, with ten in each condition.

Apparatus

Same as Experiment 1.

Procedure

Everything about the procedure was same as Experiment 1, except that baseline relations were trained concurrently in Experiment 2. Specifically, the AB, BC, CD, and DE trials for all three potential classes were presented randomly in the training block, with the block being repeated until all relations produced the mastery level of responding. All other aspects of the protocol were the same as in Experiment 1. Two conditions were studied: A-as-PIC and A-as-S^D. The stimuli used in each class were as listed in Fig. 1.

Results and Discussion

Acquisition and Maintenance of Baseline Relations The acquisition of the baseline relations was much faster in the A- as-PIC condition than the A-as-S^D condition, requiring a median of 306 and 360 trials to reach mastery, respectively. Medians were used to characterize acquisition because of extreme scores produced by a few participants. A t-test, however, revealed no significant difference between the conditions in terms of the number of trials needed to acquire the baseline relations, $t\,(18)=-1.05$, $p>0.05$. Thus, type of stimuli did not influence the speed of acquiring the baseline relations.

When errors during acquisition were considered, 38 % of the trials produced errors for the participants in the A-as-PIC condition compared to 42 % of trials with errors for the participants in the A-as-S^D condition. Error rate during acquisition was therefore not influenced by the type of stimuli used.

Table 4 Comparison of baseline acquisition during Experiments 1 and 2 for participants who did not form classes

	Trials to acquisition		% Errors	
	A-as-PIC	A-as-S^D	A-as-PIC	A-as-S^D
Serial	576	378	23	31
Concurrent	306	360	38	42

Note. The table shows the median number of trials needed during the acquisition of baseline relations and the percentage of errors made during acquisition

A comparison of trials to acquisition for the two conditions in Experiment 2 with comparable data from Experiment 1 shows how serial and concurrent training influenced baseline acquisition for participants who did not form classes. As shown in Table 4, Acquisition rates, then, were not significantly different from comparable acquisition rates produced by serial and concurrent training. Since no participants formed classes in Experiment 2, it was not possible to compare the effects of serial and concurrent training on baseline relations for participants who formed equivalence classes.

Table 4 also shows the percentage of acquisition trials that were errors in each of the conditions in the two experiments. In Experiment 1, 23 % and 32 % of the acquisition trials produced errors in the A-as-PIC and A-as-SD conditions during serial training, whereas 38 % and 42 % of acquisition trials produced errors during concurrent training in the A-as-PIC and A-as-S^D conditions. Error rate was also not significantly different between the two experiments.

Most participants in Experiment 2 maintained the baselines throughout the maintenance phase that consisted of 144 trials, with a minimum number of errors. Therefore, the performances observed during the maintenance of baseline relations were not influenced by the stimuli used, or the speed of acquiring the baseline relations. These findings are similar to those obtained during the maintenance phase of Experiment 1.

Equivalence Class Formation None of the participants formed equivalence classes in either condition in Experiment 2. Thus, the inclusion of a meaningful picture or an abstract shape that functioned as an S^D did not result in class formation when the baseline relations were trained on a concurrent basis. This finding demonstrates that the class-enhancing effect of a meaningful stimulus or a meaningless stimulus that has acquired a discriminative function can be completely overshadowed by the protocol used to establish an equivalence class.

Performances Evoked by Derived Relations Probes Even though none of the participants formed classes, the concurrent training of the baseline relations differentially influenced the performances produced by the various probes presented in the test block, and both training conditions had the same effect of pattern of responding across probe types. These results are illustrated in the bottom panel of Fig. 3. During the derived relations tests that followed concurrent training, only 30 % of participants maintained the mastery level of responding on the baseline relations after A-as-PIC and A-as-S^D training. When the symmetry probes were considered after concurrent training of the baseline relations, only 20 % of the participants reached the criterion for symmetry and none of the participants responded at the criterion level in the presence of the one-, two-, and three-node probes, once again after A-as-PIC and A-as-S^D training.

Derived Relations Performances after Serial and Concurrent Training Figure 4 provides a comparison of the effects of serial training (Experiment 1) and concurrent training (Experiment 2) on the baseline relations and the derived relations performances produced by the participants who did not form the equivalence classes. When baseline training was conducted with pictures as the A-stimuli, the percentage of participants who responded in a class consistent manner to the

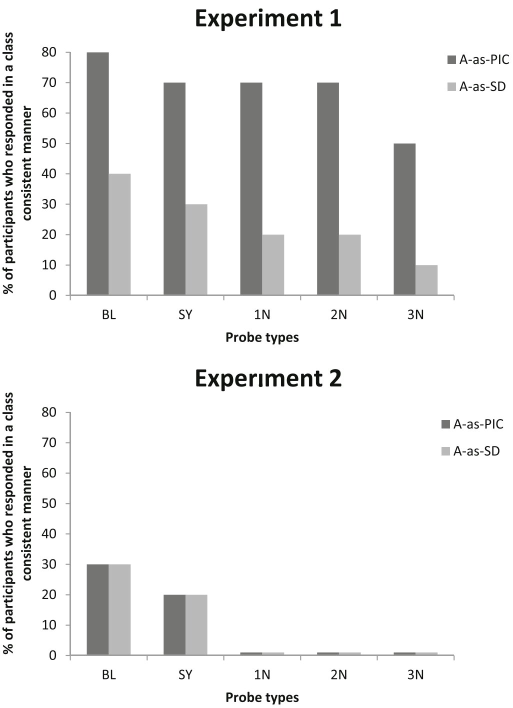

Fig. 4 The effect of serialized and concurrent training of the baseline relations on the percentage of participants who responded in a class consistent manner to the baseline relations and each of the derived relations probes presented during the test blocks for the A-as-PIC and A-as-S^D conditions in Experiment 1 [top panel, and Experiment 2 (bottom panel)]. BL=Baseline relations, SY=Symmetry, 1 N=One node, 2 N=Two nodes, and 3 N=Three nodes

derived relations probes was greater after serial training than concurrent training. That difference was much smaller when the A-stimuli were abstract shapes that functioned as S^Ds. Thus, even with participants who did not form classes, serialized training produced better criterion level responding to derived relations probes than concurrent training.

General Discussion

Modulation of Class Enhancement by Meaningful Stimuli The results of Experiments 1 and 2 clarify the conditions that enable class enhancement by the inclusion of a meaningful stimulus as a member of a potential equivalence class. In Experiment 1, training was done serially, and 70 % and 40 % of participants formed equivalence classes when a meaningful stimulus was included as the A or E member of the class. In addition, the A and E stimuli were included in baseline relations that were trained first and last, respectively. Thus, class enhancement was modulated by either the order of training the relation that included the meaningful stimulus, and/or the location of the meaningful stimulus in the nodal structure of the class. In Experiment 2, the meaningful stimulus was used as the A member of the potential class and all baseline relations were established concurrently. Thereafter, none of the participants formed equivalence classes. Since all of the baseline relations were established at the same time, order of training was eliminated as a possible modulator of class enhancement. In Experiment 1, then, the class enhancement effect observed after serial training was due to the order of training.

A second implication of this interpretation is that the location of a meaningful stimulus in the structure of a class might not be a modulator of the class enhancement effect of a meaningful stimulus. Such an inference, however, may not be valid, since 40 % yield was observed in the E-as-PIC condition. Additional research will be needed to empirically evaluate whether and to what likelihood of class formation is influenced by the location of a meaningful stimulus in the structure of an equivalence class. To summarize, the class-enhancing effect of a meaningful stimulus is not absolute; rather, it is an interactive function of the stimulus itself and the order of training the baseline relations for an equivalence class that included these stimuli.

These effects were demonstrated in the context of multinodal equivalence classes with a linear series nodal structure. Prior studies of equivalence class formation that used the serialized training of baseline relations also produced results similar to those obtained in the present experiment, but they occurred in the context of one-node equivalence classes (e.g., Arntzen 2004; Arntzen and Lian 2010; Fields et al. 2012). Taken together, these results demonstrated that the class-enhancing effect of order of introduction of a meaningful stimulus was independent of the number of nodes in an equivalence class.

In the present experiments, the meaningful stimulus was introduced first while establishing the AB relations or last while establishing the DE relations, and these two conditions produced large difference in likelihood of equivalence class formation. These conditions, then, represented the two end-points of the temporal extreme for the inclusion of the meaningful stimuli in the baseline relations. As such, it does not indicate how the intermediate inclusion of a meaningful stimulus would influence class formation. A partial answer to that matter can be gleaned by considering the outcomes reported by Fields et al. (2012), who studied the formation of the same classes by equivalent participants where the meaningful stimuli were included in the middle of training; the pictorial stimulus (i.e., C), was included in the second and third trained relations (i.e., BC and CD), after the first trained relation (i.e., AB), and before the last trained relation (i.e., DE). When the data were combined for the present experiment and that conducted by Fields et al. (2012), the introduction of the meaningful stimuli at the beginning, middle, and the end of training produced 70 %, 80 %, and 40 % yields. Although this analysis clarifies the shape of a class enhancement function, that function also raises a number of unanswered questions. Does the 10 % increment when using the pictures as the C stimulus instead of the A stimuli reflect natural variation but no real difference? Does the 40 % decrement in yields when using pictures as the C and E stimuli reflect endpoints of a continuously graded function or a step-like decremental function between C and E? Answers to these questions can be obtained by conducting a study in which the pictures will be used as A, B, C, D, or E stimuli in different conditions. Any systematic outcome of such an experiment will refine our knowledge regarding the modulation of the class-enhancing effects of meaningful stimuli.

Mechanism of Class-Enhancement Regardless of the effects considered above, how does the initial introduction of a meaningful stimulus enhance class formation while its later introduction does not? As noted by Fields et al. (2012), and Travis, Fields, and Arntzen (in press) , a meaningful stimulus most likely serve as a discriminative stimulus for responses, as a member of at least one other conditional relation, and as a member of many stimulus classes. Thus, the meaningful stimulus is a member of a rich network of stimulus-stimulus and stimulus-response relations.

When introduced first in training, the new and abstract or meaningless stimuli that are to become members of the new equivalence classes become linked to an already established network of stimuli and responses. As such, the meaningful stimulus acts as a node that links the new stimuli with the network of associated stimuli and responses that are related to the meaningful stimulus. The meaningful stimulus, then, acts as an anchoring point or priming event that facilitates the linkage of the new stimuli to each other and to all of the stimuli in the network of associates. That anchoring effect is diminished with the late introduction of the meaningful stimulus, because it is not available for use as a linking node during the establishment of the relations among the stimuli in the to-be-formed class. In Experiment 1, we also found that the class enhancement effect produced by an abstract stimulus that acquired one discriminative function was less than that observed by a meaningful picture. Presumably the abstract stimuli had fewer associates than the pictures. Assuming the class enhancement is directly related to number of associates, it would follow that abstract stimuli that had acquired discriminative functions would have a lesser anchoring effect and produce a lower likelihood of class enhancement. Although this prediction was confirmed, additional research will be needed to evaluate the validity of this analysis.

Naming and Equivalence Class Formation Many studies have proposed that naming plays a pivotal and facilitative role in equivalence class formation (Bentall et al. 1993; Dickins et al. 1993). If it is assumed that the meaningful stimuli in the present experiment occasion naming (a discriminative function), similar likelihoods of class formation should be obtained regardless of the order of introduction of the meaningful stimuli. That, in fact, did not occur. At the least, the influence of naming would appear to be substantially attenuated by the point in training at which a nameable stimulus is introduced.

Summary These experiments provide further evidence that the inclusion of a meaningful stimulus in a set of otherwise meaningless stimuli enhances the formation of equivalence classes among those stimuli. To a lesser extent, the same results accrue with abstract stimuli that have acquired discriminative functions prior to class formation. Fields et al. (2012) and Travis, Fields, and Arntzen (in press) have noted that meaningful stimuli serve as discrimanda for particular responses, as members of conditional relations, and as members of other categories. Because of all of these relations, the inclusion of a meaningful stimulus in a set of nominally meaningless stimuli enhances the likelihood of forming a class among all of those stimuli. The main finding of the present experiments showed that the magnitude of the enhancement effect for a meaningful stimulus was not absolute; rather, it was modulated by the order of inclusion of that stimulus in the serial training of the baseline relations for a class. This outcome, then, further refines our knowledge of the factors that influence the class-enhancing effects of meaningful stimuli.

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Study 3

Training Order and Structural Location of Meaningful Stimuli: Effects on Equivalence Class Formation

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Training Order and Structural Location of Meaningful Stimuli: Effects on Equivalence Class Formation

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Abstract

Two experiments disclosed how the inclusion of a meaningful stimulus with other meaningless stimuli influences the formation of equivalence classes by all of these stimuli, and how that effect is modulated by the (a) order in which the meaningful stimulus in introduced during training, and (b) location of the meaningful stimulus in the nodal structure of the class. In Experiment 1, five groups of ten university students each were trained to form three 3-node 5-member classes (A → B → C → D → E) under the simultaneous protocol. After the serial training of the baseline relations AB, BC, CD, and DE in that order, the emergence of all derived relations was tested concurrently. When A was meaningful and B-E were meaningless, classes were formed by 60% of participants. When B was meaningful and A, C, D, and E were meaningless, classes were formed by 40% of participants. When C was meaningful and the rest were meaningless, classes were formed by 70% of participants. When D was meaningful with the rest meaningless, classes were formed by 40% of participants. Finally, when E was meaningful and the rest were meaningless, classes were formed by 20% of participants. Thus, the likelihood of class formation could have been influenced by the position of a meaningful stimulus in the structure of a class and/or their order of introduction during training. In Experiment 2, five other groups that paralleled those mentioned above, controlled for the effect of order of introduction through the concurrent training of all the baseline relations. Regardless of the location of the meaningful stimulus in the class structure (A-E), classes were formed by 0-20% of participants. Thus, the order of introducing a meaningful stimulus is a primary modulator of the class enhancing property of meaningful stimuli. By implication, the variations in yield after serial training were produced by the location of the meaningful stimulus in the class structure or the behavioral functions served by the stimuli linked by training to the meaningful stimuli.

Keywords: Meaningful stimulus, stimulus equivalence, simultaneous protocol, serialized, order of training.

When a stimulus that controls a response can be replaced with another perceptually disparate stimulus without altering the probability of responding, the two stimuli are functionally interchangeable in some sense**.** In most cases, after some training, these perceptually disparate set of stimuli that are initially unrelated are said to have become equivalent to each other and act as members of an equivalence class when they show the properties of reflexivity, symmetry, and transitivity (Sidman & Tailby, 1982). For instance, after training a child who only speaks and understands one of the local languages from Ghana to match "*kraman*" (the Akan word for dog) to the English word *dog* and then is trained to match *dog* to *hund* (the Norwegian word for dog), the emergence of untrained relations that show reflexivity (kraman→kraman, dog→dog, hund→hund); symmetry (dog→kraman, hund→dog); and transitivity (kraman→hund) will demonstrate that all of the words function as members of one equivalence class, and thus, one word can be used in place of the other without altering the probability of a response occurring. Stimulus equivalence is thus, synonymous with stimulus substitutability (Green & Saunders, 1998).

The formation of equivalence classes has been documented with a diverse range of participants such as typically developing children (e.g., Arntzen & Lian, 2010), autistic children (e.g., Arntzen, Halstadtro, et al., 2010), and typically developing adults (e.g., Fields et al., 2012). The classes that have been formed have had different training structures that have varied in terms of number of nodes and directionality of training (e.g., Arntzen, Grondahl, & Eilifsen, 2010; Arntzen & Hansen, 2011) and have been formed using a variety of training protocols (Imam, 2006). The sensory modality of stimuli used as class members has also been shown to influence the formation of equivalence classes. For example, classes have been formed using stimuli that are visual (e.g., Fields et al., 2012), tactile (e.g., Belanich & Fields, 1999), and gustatory (e.g., L.

J. Hayes et al., 1988). When visual stimuli have been used, they have bee abstract (e.g., Sidman et al., 1982) or meaningful or familiar pictures (e.g., Fields et al., 2012).

Many studies have shown that the inclusion of a meaningful or familiar picture as a member of the potential class enhanced the formation of equivalence classes (Arntzen, 2004; Arntzen & Lian, 2010; Fields et al., 2012). In addition, the inclusion of a meaningful stimulus at different temporal points in training influenced likelihood of equivalence class formation (Arntzen, 2004; Fields et al., 2012; Nartey et al., 2014c). In Nartey et al. (2014c) participants attempted to form three 3-node 5-member equivalence classes that consisted of four abstract stimuli and one meaningful stimulus. After the training of AB, BC, CD, and DE relations in a serial order, classes were formed by 70 % of participants when the A-stimuli were familiar pictures and were members of the first-trained AB relations, while the B-E stimuli were abstract stimuli. When the E-stimuli were familiar pictures and were members of the last-trained DE relations, while the A-D stimuli were abstract stimuli, classes were formed by only 40 % of participants. Thus, the formation of large multi-nodal classes could have been influenced by the location of a meaningful stimulus in the structure of a class (i.e., A or E) and/or their order of introduction during training (first or last). In that study however, the effect of the use of pictures as B, C, and D were not explored.

Fields et al. (2012) explored the use of the meaningful stimulus as the C-member of the class. None of the participants formed classes when all of the stimuli were abstract. However, when the A, B, D, and E stimuli were the same abstract stimuli but the C stimuli, which served as nodes, were meaningful pictures, 80 % of participants formed classes. In systematic explorations,Travis et al. (2014) and Nedeclu (2014) also found that the use of the meaningful stimulus as the middle node had a substantial class-enhancement effect. Thus, the formation of large multi-nodal classes was also enhanced by the inclusion of a meaningful stimulus as the middle node.

Experiment 1

When the results of all of these experiments are considered, the use of a meaningful stimulus as the A or C member of the class appeared to produce similar high yields, while the use of the meaningful stimulus as the E member of the class produced a lower yield. This conclusion, however, must be leavened because the A and E data were obtained in one experiment and the C data in another; thus, the relative effects of the A and C stimuli could have reflected the influences of other variables that were idiosyncratic and confounded the effects attributed to the A and C stimuli. That interpretive problem could be obviated by conducting a single experiment that used the meaningful stimulus as the A, C, or E member of an equivalence class. In addition, such an experiment could also use the meaningful stimuli as the B, or D members of the equivalence classes to obtain a comprehensive analysis of the class enhancing effects of including a meaningful stimulus on class enhancement. Conducting such an experiment would determine whether the class enhancement effect of a meaningful stimulus declines systematically as its location in a class varies from the C to the D to the E stimulus, or whether it drops precipitously such that the same low yield would be produced when the meaningful stimulus is used in the D and the E locations in the class structure. Either outcome would inform the development of plausible theoretical account of the variables responsible for modulating the class enhancing effects of a meaningful stimulus that is a member of a to-be-formed equivalence class.

The present experiment consisted of 5 groups. In each, the participants attempted to form 3-node 5-member equivalence classes with an A→B→C→D→E training structure, where four of the five stimuli were abstract and one was a meaningful stimulus. Baseline relations were established in a serial order as AB, BC, CD, and DE respectively. The simultaneous protocol was used for training and testing. In the different groups, the meaningful stimulus was included in the set of other meaningless stimuli as the A, B, C, D, or E member of a to-be-formed class. This experiment then documented how the likelihood of equivalence class formation was influenced by the inclusion of a meaningful stimulus as each member of a to-be-formed class. The results of the experiment identified how order of introducing the meaningful stimulus and the location of the stimuli in the nodal structure of the class influences the class enhancing effect of the meaningful stimulus on equivalence class formation.

Method

Participants

Fifty university students (27 males and 23 females) between the ages of 19 to 25 years voluntarily participated in this study. The average age was 21years (*SD*=1.4). None of them had any prior knowledge of stimulus equivalence research and methodology. Participants were assigned on a block-randomized basis to one of five experimental groups.

Apparatus

Setting. The experiments were conducted in the graduate seminar room of the Department of Psychology at the University of Ghana, Legon. The seminar room measures approximately 5m square and is furnished with tables and chairs.

Hardware. The experiments were conducted on an HP Compaq nc6320 laptop computer that used an 1828 MHz Intel Centrino® processor, and had a screen with a 16.8 in diagonal length and a 16 × 9 horizontal-to-vertical ratio. An external mouse was used by participants to control the position of the cursor throughout the experiment.

Software. All sessions for training and testing of conditional discriminations for all of the participants were conducted with a software program version 3.12 made by Psych Fusion Software in collaboration with the second author. The software controlled the presentation of all stimuli and also made recordings of data including the trial number, number of training trials, reaction time to sample and comparison stimuli, whether or not participants made the correct/incorrect comparison choice, and whether or not programmed consequences was delivered. Finally, the software provided a summary of symmetry, transitivity, and equivalence tests as well as the duration of the experiment.

Stimuli. Stimuli sets used in the experiment are shown in Figure 1. The top section of the figure shows the 15 abstract stimuli used as members of the equivalence classes whilst the bottom section shows the 3 familiar picture-stimuli used to replace the A, B, C, D, or E abstract stimuli in the A-as-PIC, B-as-PIC, C-as-PIC, D-as-PIC, or E-as-PIC respectively. The abstract stimuli were displayed in black and the picture stimuli in colors, both on a white background. The size of the stimuli as presented on the computer monitor was 9.4cm x 3.4 cm, which also corresponded to the touch sensitive area of the screen.

Procedure

Design. The participants were randomly assigned to one of the following five groups: (1) A-as-PIC, (2) B-as-PIC, (3) C-as-PIC, (4) D-as-PIC, and (5) E-as-PIC. In the A-as-PIC groups, the A-stimuli were the familiar pictures shown in the bottom section of Figure 1 whiles B-E stimuli were the same abstract stimuli in the top section of the Figure. The B, C, D and E stimuli in the B-as-PIC, C-as-PIC, D-as-PIC, and E-as-PIC groups respectively were the familiar pictures while the other stimuli were abstract.

Preliminary information. Upon arrival at the experimental setting, participants were made to take a seat and given an informed consent document to read. The document informed participants that, they are about to participate in an experiment in the field of behavior analysis which will last approximately one and half-hours; that, they are required to respond to certain stimuli on the screen of a computer with mouse clicks; and that, there are no known harmful effects of participating in the study. They were also told they could choose to withdraw from the experiment at any time without any negative consequences. After reading this information on a form, those who agreed to be participants signed the form and began the experiment.

Card sorting. The participants in the experiment remained seated in the experimental cubicle and were given the 15 plastic-laminated cards that corresponded to the stimuli to be used in the group to which the participant was assigned and told to "put them into groups". All participants were presented with 12 abstract stimuli cards and the three picture C stimuli. After the experiment, participants were asked to "put them into groups" again.

Instruction. After the pre-class formation sorting task, the participants remained seated in the experimental cubicle behind the computer and were presented with the following instructions on the computer screen:

> "In a moment a stimulus will appear in the middle of the screen. Click on this by using the computer mouse. Three stimuli will then appear in three corners of the screen. Choose one of them by clicking on it with the mouse. If you choose the stimulus we have defined as correct, words like "very good", "excellent", and so on will appear on the screen. If you press a wrong stimulus, the word "wrong" will appear on the screen. At the bottom of the screen, the number of correct responses you have made will be counted. During some stages of the experiment, the computer will NOT tell you if your choices are correct or

wrong. However, based on what you have learned so far, you can get all of the tasks correct. Please do your best to get everything right. Thank you and good luck!”

No further instructions were given before and after the experiment started.

Trial structure and contingencies. All participants were exposed to the simultaneous protocol to form equivalence classes with training and test trials presented in a matching to sample format. Each trial began with the presentation of the sample stimulus in the middle of the screen. Responding to the sample stimulus by a mouse click on it was immediately followed by the presentation of the three comparison stimuli at three of the four corners of the screen, while the sample stimulus still remained on the screen. The location of the corners used to present the comparisons was randomized across trials.

A comparison was selected by moving the mouse cursor to it and then left-clicking the mouse. The selection of the correct comparison stimulus on a trial resulted in the removal of the sample and comparison stimuli and the presentation of the words *correct*, *very good*, *super*, or *excellent* on the screen. Clicking on one of the incorrect comparison stimuli also resulted in the removal of the stimuli and the presentation of the word *wrong* on the screen. If a programmed consequence was presented after the selection of a comparison, it was displayed in the middle of the screen for 1,000ms. Termination of the programmed consequences message was followed with a 500ms inter-trial interval. Between trials, the mouse cursor was returned to the center of the screen.

Equivalence class formation. The simultaneous protocol was used to establish equivalence classes. First, all the baseline relations for the equivalence classes were trained in a sequential manner until the achievement of a mastery criterion and were then maintained with decreasing proportions of programmed consequences. Then, all of the baseline relations together with all derived relations were presented randomly in an emergent relations test block.

Acquisition of baseline relations. All baseline relations were trained in five serialized phases with feedback provided for the selection of comparisons for each trial. Phase 1 was for the training of AB relations in a block containing nine trials, three each of the three classes. A mastery criterion of at least 90% correct was required for the training of each relation. A total number of 9 correct trials out of 9 trials were therefore required to proceed to the training of the next relation in the first 4 training phases. Participants repeated each block till the mastery criterion was met. Phases 2, 3 and 4 were the same as phase 1 except that BC, CD, and DE relations were trained in each phase, respectively. An equalization block was then used to ensure that each of the baseline relations was presented the same number of times.

Phase 5 involved the inclusion of all the relations trained in the first four blocks: AB+BC+CD+DE. The trials presented in the Phase 5 block were A1B1-B2-B3, A2B1-B2-B3, A3B1B2B3, B1C1C2C3, B2C1C2C3, B3C1C2C3, C1D1D2D3, C2D1D2D3, C3D1D2D3, D1E1E2E3, D2E1E2E3, and D3E1E2E3. For each trial representation, the first stimulus is the sample and the other three are the comparison stimuli whereas the underlined comparison is the correct comparison. In each trial, a participant was expected to match the samples to the correct comparisons. Phase 5 contained 36 trials (3 presentations of each of the 12 trial types listed above). The block was repeated until correct comparisons were selected on at least 90% of the trials of each baseline relation in a block (the mastery criterion), defining the acquisition of the baseline relations.

Maintenance of baseline trials. Participants continued with training blocks with reduced programmed consequences. The percentage of trials in a block that produced feedback after the last acquisition of baseline trials phase was reduced to 75%, 50%, 25%, and 0% in that order. This cross-phase programmed reduction of reinforcement density was necessary to ensure that the baseline relations were still intact even without reinforcement. For each level of feedback, the trials that produced feedback were randomized in a block. The maintenance phase was completed with the mastery level of responding in the last block of 36 baseline trials with no feedback. Table 1 shows a full overview of each of the experimental phases.

Emergent relations test block. The last block with no programmed consequences was followed by an emergent relations test block that contained 180 trials. Of the 180 trials, there were 36 baseline trials; 36 symmetry trials; 54 one-node trials; 36 two-node trials; and 18 three-node trials. All of the trials were randomly presented and without programmed consequences.

The emergent relations test block was divided into two halves of 90 trials each to provide a measurement of either the immediate or delayed emergence of equivalence classes. The first and second sets were referred to as Test Blocks 1 and 2, respectively. Equivalence classes were said to be formed if at least 90% correct comparisons consistent with experimenter-defined classes were selected in one of the test blocks. Immediate emergence occurred when the criterion was reached in the first test block. In those instances, the second test block measured the maintenance of the classes. Delayed emergence of the classes, on the other hand occurred when the criterion was not reached in the first test block but was then reached in the second test block. A participant was said to have failed to form classes if sub-mastery performances were obtained in both test blocks.

Results and Discussion

Acquisition of baseline relations

Figure 2 shows the median number of trials needed to acquire the baseline relations in each condition. The participants who formed equivalence classes in the A-, B-, D-, and E-as-PIC groups acquired the baseline relations taking a median of 541 trials with no significant variation across these conditions, Kruskal-Wallis (4) = .2215, p =.974. In contrast, the baseline relations for the participants in the C-as-PIC group were acquired in a median of 396 trials, a value that indicated significantly faster acquisition than that observed in the other conditions, Mann-Whitney, U=98, p =.032. Thus, the speed of acquiring the baseline relations was influenced by the ordinal introduction and the structural location of the meaningful stimuli in the training structure.

There were no systematic or significant differences in acquisition speeds for participants who did and did not subsequently form equivalence classes. Finally, when errors were considered, errors occurred in an average of 19% of trials, and did not vary systematically across experimental conditions or between participants who did or did not subsequently form the equivalence classes.

Equivalence class formation

Table 2 shows the performances produced on both of the derived relations test blocks, the immediate or delayed emergence of the equivalence classes indicated by the derived relations test performances, and the outcomes of the sorting tests for each participant in each group. As shown, 27 participants responded substantially below mastery in both test blocks, and thus failed to form equivalence classes. An additional 16 participants responded at the mastery criterion in both test blocks, indicating the immediate emergence of the classes in Test block 1 and their maintenance in Test block 2. Another seven participants did not respond at criterion in the first test block but did so in the second test block, which documented the delayed emergence of the equivalence classes. Six of these seven participants (4720, 4725, 4706, 4729, 4716, and 4710) produced correct responses that approximated the mastery level in the first test block, which suggests that equivalence classes may have emerged on a delayed basis but did so in the latter portion of the first test block, and were then maintained in the second test block.

Table 2 was also used to assess how each experimental group influenced the immediate and delayed emergence of equivalence classes. When immediate emergence is considered, 50% yields were obtained when the meaningful stimuli served as the A or C class members, lower 20% yields and 30% yields were obtained when the meaningful stimuli served as the B or D class members respectively, and a very low 10% yield was obtained when the meaningful stimuli served as the E class members. Finally, when the C-, D-, and E-as-PIC groups were considered, the yield declined systematically when the meaningful stimulus served as the C, D, and E class members, respectively.

When the delayed emergence of the classes was considered, each group produced essentially the same small increments in yield; an addition of one or two participants per group. When both forms of emergence are considered, the immediate emergence of equivalence classes was a non-monotonic function of the class member that was a meaningful stimulus. In addition, the class member that was a meaningful stimulus did not influence likelihood of the delayed emergence of the classes.

Figure 3 shows how each group influenced the overall likelihood of equivalence class formation. Overall emergence was defined as the percentage of participants in a group who formed classes regardless of rate of emergence. It also indicates how participants sorted the stimuli prior to and after exposure to the simultaneous protocol. Each cluster of bars in this panel represents data for a specific group, with the leftmost bar showing the pre-class formation sorting, the rightmost represents post-class formation sorting and the middle bars representing performances in the derived relations test, and the middle bar in each cluster showing the overall emergence of the classes.

When the pattern of overall yields was considered, very similar high yields were obtained when the meaningful stimuli served as the A-, or C-member of a class. Similar and somewhat lower yields were obtained when the meaningful stimulus was used as the B or D stimulus in a class, and a very low yield was obtained when the meaningful stimulus served as the E-member of the class. In addition, yield declined in a linear manner when the meaningful stimulus served as the C, D, and E member of a class, respectively. Finally, the actual value of each overall yield, however, was 10–20% greater than the immediate emergence values because overall yield also included participants who showed the delayed emergence of the equivalence classes.

Card sorting

Table 2 and Figure 3 depicted the results of the sorting tests. When the sorting performances were analyzed, none of the participants sorted the stimuli into any of the experimenter defined classes prior to the class formation training. After exposure to the simultaneous protocol, 24 of the 50 participants across all of the groups sorted the stimuli into the three experimenter-defined classes. The remaining participants sorted the stimuli into clusters that did not correspond to the experimenter-defined classes.

All but one of the participants who formed classes during the derived relations tests also showed maintenance of those classes during the sorting test. Participant 4714 formed classes in the derived relations test but failed to do so in the sorting test. All other participants who did not form classes also did not sort the cards into the three experimenter-defined classes. Also, two participants (4748 and 4738) who did not form classes during the derived relations test sorted the cards into the experimenter-defined classes afterwards. However, their performances in the derived relations test were almost equal to mastery level. Therefore, for 94% of the participants (47 of 50), the outcome of the sorting task corresponded to their performances in the derived relations test.

This result replicates previous findings (e.g., Fields et al., 2014; Nartey, Arntzen, & Fields, 2014a) that showed class based behavior generalized between two trial formats: matching to sample trials during class formation and sorting during post class formation testing. The data, thus, show that the inclusion of a meaningful stimulus and its introduction in the training of baseline relations did not affect the seeming agreement between the two test formats.

Summary. The class enhancing effects of including a meaningful stimulus in a set of other meaningless stimuli can enhance the formation of an equivalence class by those stimuli. That class-enhancing function, however, is not constant. Rather, it is modulated by its order of introduction during the serial training of the baseline relations and/or by its' location in structure of the class.

Experiment 2

The enhancement of class formation by the inclusion of a meaningful stimulus in Experiment 1 could have been influenced by its order of introduction during training and/or its' location in the structure of a class. These two possible determinants of class enhancement could not be isolated in Experiment 1 because they co-varied with each other.

In the serial training relatively high yields were obtained when the meaningful stimulus were introduced early in training and declined when introduced later in training. If order of introduction, was the determinant of class enhancements, the concurrent training of all baseline relations would eliminate any order effect. If order was the determinant of class enhancement, the concurrent training of the baseline relations should suppress the class enhancement seen when the meaningful stimulus was introduced early in training and should approximate the low yield observed when the meaningful stimulus was introduced last in training. Alternatively, concurrent training resulted in the same pattern of yields seen in Experiment 1, it would indicate that order or introduction was not the factor that modulated the enhancing effect of a meaningful stimulus on equivalence class formation.

Experiment 2, then, replicated Experiment 1 with one exception; all of the baseline relations were trained concurrently instead of serially. Yields were compared across the five conditions in Experiment 2 and were also compared across the two experiments for each of the five conditions: A-as-PIC, B-as-PIC, C-as-PIC, D-as-PIC, and E-as-PIC.

Method

Participants

Fifty university students, 28 males and 22 females between 18 and 25 with an average age of 20 years (SD=1.71). All of the participants were naïve in terms of knowledge of stimulus equivalence research and methodology and were randomly assigned to five groups of ten participants each.

Apparatus

Same as Experiment 1.

Procedure

With the exception of the baseline relations that were trained concurrently, everything about the procedure used in Experiment 2 was the same as Experiment 1. Thus, the AB, BC, CD, and DE trials for all three potential classes were presented randomly in the training block, with the block being repeated until all relations produced the mastery level of responding. Five groups were studied: A-as-PIC, B-as-PIC, C-as-PIC, D-as-PIC, and E-as-PIC. The stimuli used in each class were the same used in Experiment 1 as listed in Fig. 1.

Results and Discussion

Acquisition of baseline relations

Median number of trials needed to form the baseline relations were computed for each group. The acquisition speed of the baseline relations was fastest for the participants in the A-as-PIC group (a median of 342 trials) and was slowest for the participants in the C-as-PIC group (a median of 774 trials). A Kruskal-Wallis H test showed that there was a statistically significant difference in the speed of acquisition among the different groups, $\chi^2 (4) = 13.044$, $p < .05$.

In terms of median errors made during acquisition of the baseline relations, the D-as-Pic group recorded the least (156), while the C-as-PIC group had the most (313.5). There were no significant differences among the groups, $\chi^2 (4) = 7.707$, $p > .05$.

Figure 4 shows a comparison of the acquisition speed for the baseline relations in Experiment 1, where the baseline relations were presented in a serial order, and Experiment 2 where the baseline relations were established concurrently. The speed was generally faster during serialized training than it was in the concurrent training. This was confirmed by a U test, $U = 900$, $p =.015$, $r =.24$.

Across experiments, there were similar trials to acquisition for the A, B, D, and E groups. In the C group, acquisition was much slower in Experiment 2 than in Experiment 1. Thus, the acquisition speed was not influenced by the training arrangement for the A, B, D, and E groups.

With the C group, the serialized training resulted in a faster acquisition speed than the concurrent training.

In terms of absolute number of errors during baseline acquisition, a U test showed that significantly fewer errors were needed to acquire the baseline relations during serialized training than during concurrent training, $U = 210.5$, $p = .000$, $r = .72$. In terms of likelihood of errors during baseline acquisition, 19 % of the acquisition trials produced errors across all groups in Experiment 1, whereas 42 % of trials produced errors across conditions during concurrent training in Experiment 2. Thus, error rate was significantly different between the two experiments.

Equivalence class formation

Figure 5 depicts the overall yields obtained in each condition in Experiments 1 and 2. After the concurrent training of baseline relations, none of the participants formed classes in the B-as-PIC, D-as-PIC, and E-as-PIC groups, only 10 % of the participants formed classes in the A-as-PIC group, and 20 % formed classes in the C-as-PIC group. An overall statistical analysis found no significant difference among the yields in the five groups in Experiment 2, $\chi^2(4) = 3.804$, $p = .433$.

When yields obtained across Experiments were compared, greater yields were obtained when baseline relations were established in a serialized order than when they were established concurrently: a difference that was statistically significant, $\chi^2(1) = 18.32$, $p < .0001$. Based on visual inspection, the pattern of yields across each condition was the same as that seen in Experiment 1 but with greatly attenuated levels in the A, B, C, and D conditions and the same very low levels in the E condition.

For each condition, yields were significantly greater after serial training than concurrent training in the A-as PIC condition (χ^2 (1) = 5.495, p = .019, the C-as-PIC condition (χ^2 (1) = 5.015, p = .025), and the D-as-PIC condition (χ^2 (1) = 5.00, p = .025). In contrast, no significant difference in yield was found in the B-as-PIC condition (χ^2 (1) = 2.400, p = .121) and the E-as-PIC condition groups (χ^2 (1) = 1.053, p = .305).

To summarize, in four of the five groups (A, B, C, and D) the concurrent training of baseline relations overshadowed the class-enhancing effect of the inclusion of a meaningful stimulus that were seen in Experiment 1. Thus, the class-enhancing effect of a meaningful stimulus was substantially modulated by its order of introduction during training, and much less so by its' location in the structure of a class.

General Discussion

In Experiment 1, relatively high and similar percentages of participants formed classes when a meaningful stimulus were used as the A, or C member in a class. Lower and equal yields were produced when the meaningful stimulus was used as the B or D member in a class, and a very low percentage of participants formed classes when the meaningful stimulus was the E-member of a class. A higher yield was obtained when the meaningful stimulus was the middle node. Yield was higher when the meaningful stimulus served as a member of the first trained relation (A-stimuli) than when it served as a member of the last trained relation (E-stimuli). Finally, the meaningful stimulus served as single in two conditions, as a sample when used as A and as a comparison when used as E, Each of these conditions, however, produced a large difference in yield,

Each of these findings has been reported separately in different articles. Specifically, the effects of having pictorial stimuli as C stimuli (Fields et al., 2012; Nartey et al., 2014a; Travis et al., 2014), and as A and E stimuli (Nartey et al., 2014c) . The present study explored all of these groups in a single experiment and replicated the outcomes reported in those studies. Thus, the present experiment both replicated and confirmed prior results in a single experimental context: the serial training of the baseline relations to form a 3-node-5-member class with an A→B→C→D→E training structure.

Previous experiments did not explore the inclusion in a parametric manner by using a meaningful stimulus as the B or D member of the class. That was done in the present experiment. Thus, the present experiment provided a comprehensive measure of the inclusion of meaningful stimuli on the enhancement of equivalence class formation, instead of a limited measure of conditions that produce class enhancement.

Although the present experiments showed relative differences in yield, they did not include a null group in which all of the potential class members were abstract stimuli. Therefore, while we could say that relative enhancement occurred when using a meaningful stimulus as A and C compared to the low yield obtained using the meaningful stimulus as E, it was not possible to make a claim of absolute enhancement because there was no null group. As noted in the introduction, many other experiments included a reference condition that did not use a meaningful stimulus as a class member, which would be a null condition. All produced yields that varied from 0 and 15% when the class included abstract stimuli only. These outcomes were similar to those reported in the E condition of Experiment 1 and to virtually all of the conditions in Experiment 2. Given these similarities, it is reasonable to assume that in Experiment 1, the inclusion of a meaningful stimulus as the A, B, C, and D members of a class produced absolute enhancements of class formation. The inclusion of the meaningful stimulus as the E-member of the class did not enhance class formation.

The concurrent training of baseline relations in Experiment 2 overshadowed the class-enhancing effect of the inclusion of a meaningful stimulus that was seen in Experiment 1. The results of the present experiments and of prior experiments demonstrate that the inclusion of a meaningful stimulus per se does not ensure the enhancement of equivalence class formation. Rather, there is an interaction between the inclusion of a meaningful stimulus and some parameter of the structure of the to-be-formed class and possibly the protocol used to establish the classes that influence class enhancement by a meaningful stimulus. The non-monotonic effect of the meaningful stimulus on likelihood of equivalence class formation and a consideration of the training structure, nodal function of stimuli and training order probably interacted with the meaningful stimulus and its point of insertion to account for the class enhancement.

Mechanism of class enhancement

The highest yields were obtained when the meaningful stimulus was included in the first trained baseline relation (A in AB) and when used as the middle node (C in the BC and CD relations). When included in the first trained relation, the meaningful stimulus served many functions. The possible effect of each of these functions on class enhancement will be conducted in order. As noted above, the meaningful stimulus was included in the first trained relation. A comparison of the results of Experiments 1 and 2 showed this order of training played a major role in enabling the meaningful stimulus to enhance equivalence class formation.

When the meaningful stimulus was used as the A member of the class, it also functioned as a single. Thus, this behavioral function could have enabled the meaningful stimulus to enhance class formation. That is unlikely since the meaningful stimulus also served as a single when included as the E member of the class, and yields were exceptionally low. Thus, functioning as a single did not enable a meaningful stimulus to enhance class formation.

When the meaningful stimulus served as A single, it served one of two behavioral functions, When used as the A stimulus in the AB relation, it functioned as a sample and was correlated with a high yield. In contrast, when used as the E stimulus in the DE relation, it served as a comparison stimulus and was correlated with a very low yield. Thus, the behavioral function served by the meaningful stimuli in Experiment 1 was predictive of equivalence class formation. Clearly, this correlation was confounded with order of training, Additional research will be needed to determine whether the behavioral functions served by meaningful stimuli when used as singles is causative of enhanced class formation.

During Experiment 1, a higher yield was obtained when the meaningful stimulus served as the C member of the equivalence class than when it served as the B or E members of the classes (70% vs 40%). Although the absolute yields were much lower in Experiment 2, a similar relation was found between the meaningful stimulus serving as the C vs B and D members of the class. The differential yields were correlated with the types of stimuli that were linked by training with the C, B, and D stimuli. The C stimulus was linked by training to two stimuli each of which was a node. In contrast, the B and D stimuli were linked by training to two other stimuli; in these cases, however, one was a node, and the other was a single (Fields & Verhave, 1987). Thus, likelihood of class formation was correlated with the behavioral functions of the stimuli with which the meaningful stimulus was linked by training. This structural factor may also have also modulated the extent to which a meaningful stimulus class enhances equivalence class formation. Additional research is needed to fully evaluate this possibility.

The information presented above focused on the structural parameters that have and could influence or modulate the class enhancing effects of a inclusion of a meaningful stimulus as a potential class member. It had not addressed a mechanism by which the inclusion of such a stimulus enhances class formation. One possibility is that of class expansion rather than class formation (Fields et al., 2012; Travis et al., 2014). Specifically, assuming that a meaningful stimulus is a member of a number of different categories, it is related to a very wide network of other stimuli. Thus, when embedded with other meaningless stimuli all of which becomes class members, the new class member should also become related to all of the stimuli that are related to the meaningful stimulus. As such, when a set of meaningless stimuli and one meaningful stimulus become class members, we may be witness to the expansion of an existing class rather than the de novo formation of a new and isolated class. This process, however, did not result in the formation of new classes when the meaningful stimulus was introduced at different times during training, or when all relations were trained concurrently. Thus, even if this is the mechanism of class enhancement by a meaningful stimulus, it is still subject to modulation by the protocol used for the training of the baseline relations and the position of the meaningful stimulus in the training structure of a potential class.

Conclusion

The results of these experiments replicated and extended the finding that the inclusion of a meaningful stimulus in a set of meaningless stimuli can enhance the formation of equivalence classes. However, the absolute enhancement property of a meaningful stimulus is not only by its mere inclusion in the class structure. Rather, class enhancement by the inclusion of a meaningful stimulus is modulated by primarily by the order of introduction of such a stimulus during the training of the baseline relations, and secondarily by the location of the meaningful stimuli in the training structure of the class.

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Table 1. Sequence of training and testing

Experimental phases	**Trial types**	Programmed consequences	Min. # of trials	Criterion
Acquisition of baseline trials				
Trial types presented in a random order				
1. Serialized trials	A1B1, A2B2, A3B3	100%	9	9
2. Serialized trials	B1C1, B2C2, B3C3	100%	9	9
3. Serialized trials	C1D1, C2D2, C3D3	100%	9	9
4. Serialized trials	D1E1, D2E2, D3E3	100%	9	9
5. Mixed trials (trials presented randomly)	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	100%	36	34
Maintenance : Fading of programmed feedback				
6. Mixed trials (trials presented randomly)	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	75%	36	34
7. Mixed trials (trials presented randomly)	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	50%	36	34
8. Mixed trials (trials presented randomly)	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	25%	36	34
9. Mixed trials (trials presented randomly)	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	0%	36	34
Test for derived relations				
All trial types randomly intermixed	Baseline trials			
	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	0%	36	34
	Symmetry trials			
	B1A1, B2A2, B3A3, C1B1, C2B2, C3B3 D1C1, D2C2, D3C3, E1D1, E2D2, E3D3	0%	36	34
	1 Node trials			
	A1C1, A2C2, A3C3, C1A1, C2A2, C3A3, B1D1, B2D2, B3D3, D1B1, D2B2, D3B3, C1E1, C2E2, C3E3, E1C1, E2C2, E3C3,	0%	54	49
	2 Node trials			
	A1D1, A2D2, A3D3, D1A1, D2A2, D3A3 B1E1, B2E2, B3E3, E1B1, E2B2, E3B3	0%	36	34
	3 Node trials			
	A1E1, A2E2, A3E3, E1A1, E2A2, E3A3.	0%	18	17

Table 2. Accurate selection of class indicative comparisons in the test blocks for each participants in each group in Experiment 1

Group	Participant	% correct in test block 1	% correct in test block 2	ECF	Post ECF sorting
A-as-PIC	4732	**100**	**100**	YES	YES
	4711	**100**	**100**	YES	YES
	4720	89	**99**	YES	YES
	4703	**97**	**98**	YES	YES
	4727	**94**	**98**	YES	YES
	4741	**96**	**92**	YES	YES
	4738	82	88	NO	YES
	4745	76	80	NO	NO
	4715	60	71	NO	NO
	4733	48	48	NO	NO
B-as-PIC	4707	**100**	**99**	YES	YES
	4750	**98**	**98**	YES	YES
	4706	89	**98**	YES	YES
	4725	84	**96**	YES	YES
	4734	78	79	NO	NO
	4748	83	74	NO	YES
	4709	70	64	NO	NO
	4723	60	63	NO	NO
	4743	63	56	NO	NO
	4718	58	42	NO	NO
C-as-PIC	4721	**98**	**100**	YES	YES
	4701	**98**	**100**	YES	YES
	4716	83	**100**	YES	YES
	4739	**99**	**99**	YES	YES
	4722	**97**	**99**	YES	YES
	4729	87	**99**	YES	YES
	4744	**94**	**97**	YES	YES
	4719	79	88	NO	NO
	4749	62	60	NO	NO
	4713	64	49	NO	NO
D-as-PIC	4728	**100**	**100**	YES	YES
	4730	**99**	**100**	YES	YES
	4735	**99**	**100**	YES	YES
	4710	89	**99**	YES	YES
	4724	83	81	NO	NO
	4702	62	57	NO	NO
	4742	53	56	NO	NO
	4705	64	44	NO	NO
	4747	57	43	NO	NO
	4737	51	38	NO	NO
E-as-PIC	4708	**99**	**100**	YES	YES
	4714	64	**97**	YES	NO
	4726	74	80	NO	NO
	4712	64	66	NO	NO
	4704	71	64	NO	NO
	4717	62	61	NO	NO
	4731	68	60	NO	NO
	4736	58	58	NO	NO
	4740	80	52	NO	NO
	4746	53	47	NO	NO

Figure 1. The stimuli used as members of the equivalence classes. The top section shows the 15 abstract stimuli whiles the bottom section shows the meaningful stimuli that replaced the abstract stimuli in different groups.

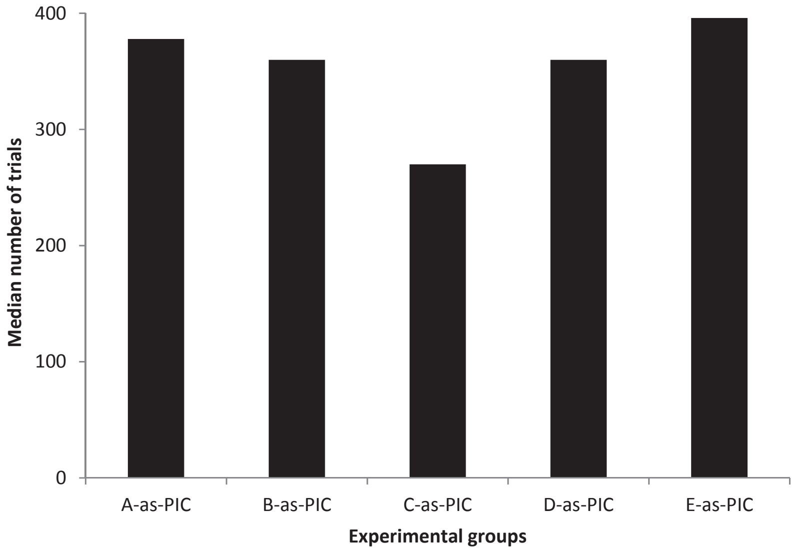

Figure 2. The median number of trials to acquire baseline relations made during acquisition of the baseline relations in all groups in Experiment 1.

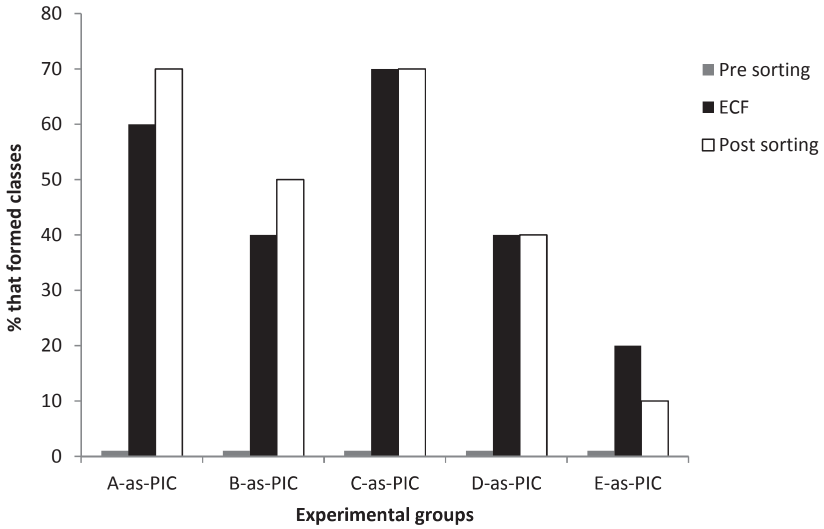

Figure 3. The percentage of participants who showed class formation in the pre- and post-class formation sorting tests, as well as those who showed overall equivalence class formation in the derived relations test in Experiment 1.

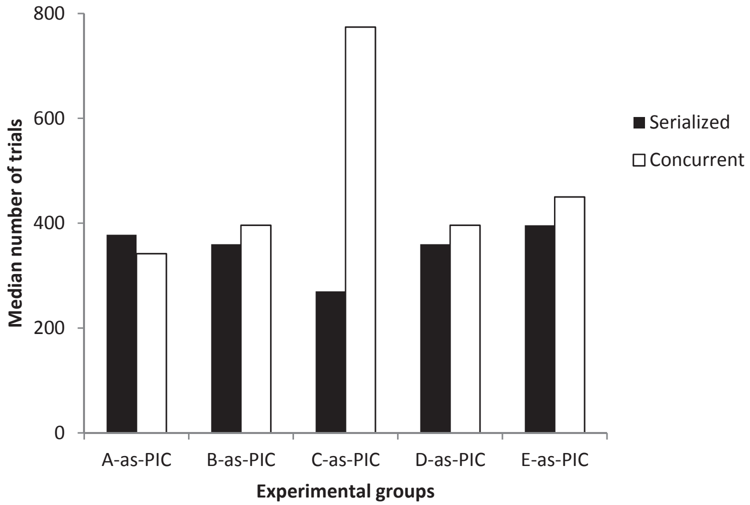

Figure 4. Comparison of baseline acquisition in Experiment 1 (serialized arrangement) and Experiment 2 (the concurrent arrangement).

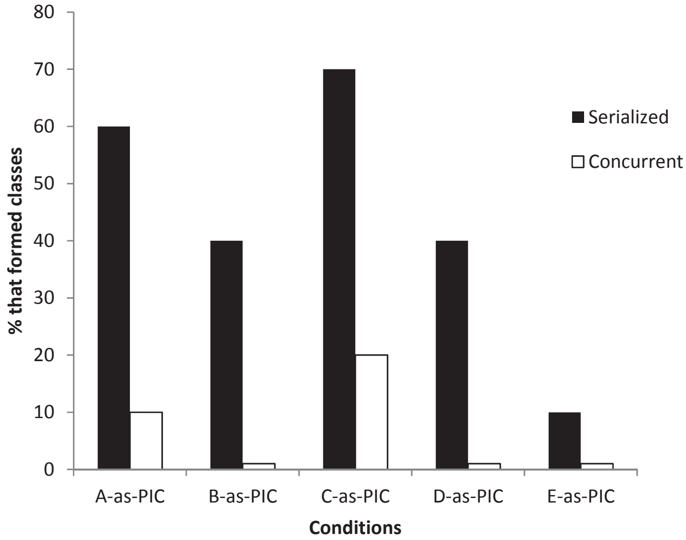

Figure 5. Yields for each condition during emergent relations test in Experiments 1 and 2.

Study 4

Identity and Delay Functions of Meaningful Stimuli: Enhanced Equivalence Class Formation

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Abstract The inclusion of a meaningful stimulus in a set of abstract stimuli enhances the likelihood of forming an equivalence class with the set. Class enhancement effects can be due to the discriminative, conditional discriminative, and class-based behavioral functions served by the meaningful stimulus. This experiment determined whether acquisition of an identity conditional discriminative function by an abstract stimulus enhances the formation of an equivalence class of which it is a member along with other abstract stimuli. Forty adults attempted to form 3 three-node five-member equivalence classes (A→B→C→D→E) using the simultaneous protocol. In the PIC group, the C stimuli were pictures and the A, B, D, and E stimuli were abstract shapes. In the ABS group, all of the stimuli were abstract shapes. In the Id-S-MTS (identity simultaneous matching-to-sample) and Id-6sD-MTS (identity 6 s delayed matching-to-sample) groups, prior to class formation, identity conditional discriminations were formed with the C stimuli using simultaneous or 6 s delayed matching-to-sample procedures, respectively. Classes were formed by 80 and 60 % of participants in the PIC and delayed identity groups, and by 0 and 10 % of participants with no prior training (ABS group) or after forming identity relations on a simultaneous basis. These outcomes were confirmed with post class formation sorting tests. Thus, a portion of the class enhancing effects of meaningful stimuli can be attributed to their presumed delayed identity conditional discriminative function. Adventitious coding or mediating behavior during identity training might have influenced acquisition of baseline relations and likelihood of class formation.

Keywords Stimulus equivalence · Identity matching-to-sample · Delayed matching · Simultaneous matching · Pictures · Stimulus meaningfulness · Sorting tests · Adults

Traditionally, meaningfulness of stimuli has been defined in terms of their denotative and connotative properties. The denotative properties of a stimulus are their defining features. For example, some of the denotative properties of a cat are that it has four legs, purrs, scratches furniture, and chases mice. The connotative properties of a stimulus are its emotive and judgmental features. For example, a cat is snuggly and makes you feel good, but can also be scary. Presumably, the depth of meaningfulness of a stimulus is directly related to the number or denotative and connotative terms with which it is associated.

Meaningful stimuli can also influence the learning of other behavior. For instance, the inclusion of a meaningful stimulus in a set of otherwise meaningless stimuli will influence the likelihood of those stimuli coming to function as members of a conceptual category called an equivalence class amongst these stimuli. An equivalence class is a finite set of perceptually disparate stimuli that initially are unrelated to each other, but through a minimal amount of training, come to be substitutable for each other. One example of this is the five words for the number 7, as written in Cyrillic, Chinese, Urdu, Korean, and Arabic. To most members of an English speaking society, before class formation, these stimuli would not be substitutable

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for each other; would not occasion the mutual selection of each other. After class formation, they would function interchangeably as witnessed by their mutual selection of each other.

The effect of meaningful stimuli on equivalence class formation has been studied using a variety of procedures, one of which is called the simultaneous protocol. In this protocol, all baseline relations are trained to mastery after which all derived relations probes are presented together (Nartey et al. in press). Class consistent responding evoked by all of these probes documents the formation of the equivalence class.

When the simultaneous protocol is used for training and testing, and all of the members of a potential equivalence class consist of meaningless stimuli, it is very unlikely that the stimuli will come to function as members of an equivalence class (Buffington et al. 1997). Indeed, it is the low basal yields produced using the simultaneous protocol that makes it a sensitive measure of variables that can enhance class formation.

Using the simultaneous protocol, when all of the members of a potential equivalence class were meaningful but unrelated to each other, there is a very high likelihood of forming a class among them if they have compatible connotative valences (e.g., Dickins et al. 1993). In contrast, much lower likelihoods of class formation were observed if the meaningful stimuli had connotatively contradictory valences (Grehan 1998; Leslie et al. 1993; Plaud 1995; Watt et al. 1991). Finally, an intermediate percentage of participants formed equivalence classes if only one of the stimuli in the set was meaningful (e.g., a picture) and the remaining stimuli were meaningless (e.g., Arntzen and Lian 2010; Fields et al. 2012). These class enhancement effects are typically attributed to the connotative/emotive properties of the meaningful stimulus, the stimuli with which the stimulus is related and the responses elicited by the stimulus (Travis et al. in press).

There is, however, an alternative account of the class-enhancing properties of meaningful stimuli, which is based on their acquired behavioral stimulus control functions (Fields et al. 2012; Tyndall et al. 2004). A meaningful stimulus can evoke the occurrence of any number of productive responses, such as saying or writing its name; thus, it would be functioning as a discriminative stimulus for each of these responses. A meaningful stimulus can occasion the selection of another stimulus such as a printed definitional statement or a printed statement of its emotive content. In each instance, the meaningful stimulus would be functioning as a member of at least one conditional discriminative relation. Finally, a meaningful stimulus can also be used interchangeably with many other stimuli; thus, it would be acting as a member of an equivalence class or a naturally occurring category composed of these stimuli. It follows, then, that some proportion of the class-enhancing effect of a meaningful stimulus could be accounted for by the presence of any combination of these stimulus control repertoires, apart from and/or in addition to their connotative or denotative properties.

Initial support for this view has been provided by Fields et al. (2012). Using meaningless stimuli designated as A, B, C, D, and E, the experiment began with the establishment of the C stimuli in different sets as discriminanda in simple successive and simultaneous discrimination paradigms. Thereafter, ABCDE equivalence classes were formed by 50 % of participants. In contrast, the same classes were formed by 0 % of participants for whom the C stimuli had no discrimination training history. In addition, the use of familiar pictures as the C stimuli resulted in the formation of equivalence classes by 80 % of participants in a group. Fields et al. (2012) concluded that the discriminative functions served by meaningful stimuli could account for a portion of their class-enhancing properties. In this experiment, the abstract stimuli that had acquired discriminative functions did not have either identifiable denotative or connotative properties. Therefore, these properties could not be invoked to account for class enhancement.

Meaningful stimuli also serve conditional discriminative functions in natural settings. These conditional discriminative functions could have been in the form of identity or arbitrary relations. In an identity conditional relation, an individual is presented with a range of sample stimuli along with a set of comparison stimuli, one of which is identical to the sample stimulus; the selection of the comparison that is identical to the sample stimulus would document the presence of an identity conditional relation. Thus, if a meaningful stimulus such as pictures of a person's son or daughter were presented as sample stimuli, the selection of the identical picture would instantiate the presence of the identity conditional discrimination. Because previously established discriminative functions enhanced class formation (Fields et al. 2012), and other functions can also be established prior to class formation, the present experiment sought to determine whether the pre-class formation establishment of identity conditional discriminations with an abstract stimulus designated as C, might also enhance the likelihood of forming equivalence classes when it is included in a set of other meaningless stimuli designated A, B, D, and E.

Identity conditional discriminations can be established on a simultaneous or a delayed basis. In both cases, the acquisition of the conditional function has been studied in the context of trials administered in a matching–to-sample format (MTS). When establishing an identity conditional discrimination in the simultaneous format, one sample stimulus is presented along with at least two comparison stimuli, one of which is identical to the sample stimulus. Reinforcement is provided for the selection of the comparison that is the same as the sample stimulus. This procedure is designated "Id-S-MTS". When established in the delayed format, the sample stimuli are presented but the sample is eliminated either by the occurrence of an observing response or by the passage of time (in this case 6 s), before the presentation of the comparison stimuli, and the participant selects a comparison in the absence of the sample. This procedure is designated “Id-6sD-MTS”.

Some research has shown that the likelihood of forming identity conditional discriminations is an inverse function of the duration of the delay interval, the time separating sample termination and comparison presentation (e.g., Berryman et al. 1963; Blough 1959). In addition, asymptotic accuracy of responding in the DMTS procedure has also been reported to be an inverse function of delay duration. On some occasions, however, terminal performances sometimes have shown to be enhanced by the occurrence of sample labeling behavior that occurs during the delay interval (Constantine and Sidman 1975).

Findings such as these, however, are not universal. In some cases, the opposite has been found; for example, Arntzen (2006) has reported that training of the baseline relations of an equivalence class using delayed matching enhanced the likelihood of class formation. In addition, Bortoloti and de Rose (2009, 2012); Bortoloti and De Rose (2012) reported increases in the “relatedness” of stimuli in an equivalence class when the baseline relations were trained using a delayed matching-to-sample trial format. Thus, the existing data do not provide a clear basis for predicting how histories of identity conditional discriminations formed on simultaneous or delayed bases will influence the likelihood of subsequent equivalence class formation.

The present experiment determined whether the prior establishment of an identity relation with one meaningless stimulus using simultaneous or delayed matching procedures would influence the likelihood of forming an equivalence class that contained that stimulus and other meaningless stimuli. In all four groups, participants attempted to form 3 three-node five-member equivalence classes that contained stimuli designated as A, B, C, D, and E. Training and testing were conducted under the simultaneous protocol. In three groups, the stimuli were abstract or meaningless shapes. In the fourth, the classes contained the same A, B, D, and E stimuli, but the C stimuli were familiar and meaningful pictures. In the ABS group, participants attempted to form the classes with five abstract stimuli, where there was no prior training in identity conditional discrimination training with any of the stimuli. In the PIC group, participants attempted to form classes with abstract A, B, D, and E stimuli and a meaningful picture as the C stimulus. In the Id-S-MTS and Id-6sD-MTS groups, identity conditional discriminations were formed with the C stimuli. Once acquired, the C stimuli were included in the ABCDE sets from which equivalence classes could emerge. A comparison of outcomes across groups documented how the prior formation of identity conditional relations in simultaneous and delayed MTS formats influenced subsequent likelihood of equivalence class formation. Finally, those results also clarified whether those functions could account for some portion of the class enhancing properties manifested by meaningful stimuli.

Method

Participants

Forty students enrolled in the University of Ghana (13 men and 27 women), who varied in age from 19 to 31 years old and averaged 22.2 years, participated voluntarily in this study. None of these participants had any prior knowledge of stimulus equivalence research and methodology. Seven other participants who started the experiment either quit or were dismissed because they did not acquire the baseline relations after 2 h of training. In each case, a new participant was recruited to replace the person who did not complete the experiment. Participants were assigned on a block-randomized basis to one of four experimental conditions, ten participants in each group. All participants had learned English from the start of elementary school, along with their native language.

Apparatus

Setting The experiment was conducted in the graduate seminar room of the Department of Psychology at the University of Ghana, Legon. The seminar room measured approximately 5 m^2 and was furnished with tables and chairs.

Hardware The experiments were conducted on an HP Compaq nc6320 laptop computer that used an 1828 MHz Intel Centrino® processor, and had a screen with a 16.8 in. diagonal length and a 16×9 horizontal-to-vertical ratio. An external mouse was used by participants to control the position of the cursor throughout the experiment.

Software All sessions for training and testing of conditional discriminations for all participants were conducted with a software program version 3.12 made by Psych Fusion Software in collaboration with first author. The software controlled the presentation of all stimuli and also made recordings of data including the trial number, number of training trials, reaction time to sample and comparison stimuli, whether or not participants made the correct/incorrect comparison choice, and whether or not programmed consequences were delivered. A summary of symmetry and equivalence tests as well as the duration of the experiment was also provided by the software.

Stimuli Stimulus sets used in the experiment are shown in Fig. 1. The two sections of the figure show stimuli used as members of the equivalence classes, which consist of 15 abstract and the three familiar picture stimuli. The C-stimuli were also used in the pretraining. The abstract stimuli were displayed in black and the picture stimuli in colors, all on a white background. Small plastic-laminated pictures sized

Fig. 1 The stimuli used as members of the equivalence classes were the abstract and familiar picture-stimuli as shown in the two top sections. The C stimuli were also used in the pretraining

3.8 cm^2 were made from the 15 abstract stimuli and the pictures to be used in the experiment. The size of the touch sensitive areas on the screen was 9.4 cm x 3.4 cm.

Procedure

Overview The experiment was conducted in six phases: Initial screening, pre-class formation categorization testing, instructions prior to training, pre-class formation identity conditional discrimination training, equivalence class formation, and post-class formation categorization test. Each phase will be described below.

Initial screening Upon arrival at the experimental setting, participants were made to take a seat and given an informed consent document to read. In the consent document, participants were told that they were about to participate in an experiment in the field of behavior analysis, and that it would last approximately 1.5 h. They were also informed that they were required to respond to certain stimuli on the screen of a computer with mouse clicks and that there are no known harmful effects of participating in the study. They were also told that they were free to withdraw from the experiment at any time without any negative consequences. After reading, those who agreed by signing the forms began the experimental protocol.

Categorization test After signing the informed consent document, the participants remained seated in the experimental cubicle and were given the 15 plastic-laminated cards that corresponded to the stimuli to be used in the condition to which the participant was assigned and told to "put them into groups". Participants in the C-abstract, C-based Id-SMTS and Id-6sD-MTS conditions were presented with 15 abstract stimuli cards, while those in the meaningful C stimulus group were given 12 abstract stimuli and the three picture C stimuli. Finally, the categorization or sorting test was re-administered at the completion of the experiment.

Instructions prior to training Upon the completion of the categorization test, participants remained seated behind the computer and were presented with the following instructions on the computer screen:

> "In a moment a stimulus will appear in the middle of the screen. Click on this by using the computer mouse. Three stimuli will then appear in three corners of the screen. Choose one of them by clicking on it with the mouse. If you choose the stimulus we have defined as correct, words like "very good", "excellent", and so on will appear on the screen. If you press a wrong stimulus, the word "wrong" will appear on the screen. At the bottom of the screen, the number of correct responses you have made will be counted. During some stages of the experiment, the computer will NOT tell you if your choices are correct or wrong. Please do your best to get everything right. Thank you and good luck!"

No further instructions were given before and after the experiment started.

Trial structure and contingencies All participants were exposed to the simultaneous protocol to form equivalence classes, and some received identity conditional discrimination training. In all cases, however, all training and testing were done using trials presented in a matching–to-sample format that had the following parameters.

Each trial began with the presentation of the sample stimulus in the middle of the screen. Responding to the sample stimulus by a mouse click on it was immediately followed by the presentation of the three comparison stimuli at three of the corners of the screen, while the sample stimulus still remained on the screen. When the participant moved the mouse cursor to it and pressed the left button on the mouse, a comparison was selected. Correct responses, in the form of choosing the correct comparison stimulus according to the experimenter designated classes resulted in the removal of the sample and comparisons stimuli and the production of the words *correct*, *very good*, *super*, or *excellent* on the screen. Any other response produced the word *wrong* on the screen. If a programmed consequence followed a selection response, it was displayed in the middle of the screen for 1,000 ms. Termination of the programmed consequences message was followed with a 500 ms inter-trial interval. Between trials, the mouse cursor was returned to the center of the screen.

Equivalence class formation The simultaneous protocol (Buffington et al. 1997) was used to establish equivalence classes. This was a three-stage process, each of which consisted of blocks of trials. First, the baseline relations for the equivalence classes were trained in a concurrent manner until the achievement of a mastery criterion. Second, the baseline relations were maintained in the presence of blocks that contained a decreasing proportion of reinforced trials. Third, all of the baseline relations as well as all derived relations were presented randomly in one emergent relations testing block.

Acquisition of baseline trials All baseline conditional discriminations were trained according to a linear series training structure, and were presented concurrently. Thus, every trial type was trained from the beginning in one block. The trials presented were: **A1**/<u>B1</u>-B2-B3, **A2**/B1-<u>B2</u>-B3, **A3**/B1-B2-<u>B3</u>, **B1**/<u>C1</u>-C2-C3, **B2**/C1-<u>C2</u>-C3, **B3**/C1-C2-<u>C3</u>, **C1**/<u>D1</u>-D2-D3, **C2**/D1-<u>D2</u>-D3, **C3**/D1-D2-<u>D3</u>, **D1**/<u>E1</u>-E2-E3, **D2**/E1-<u>E2</u>-E3, and **D3**/E1-E2-<u>E3</u> (the sample is the first letter in each string followed by the three comparisons; the correct comparison in each string is underlined). They were, however, randomly presented (See Table 1 for an overview of the experimental phases). Each of the trial types was presented three times with one from each class, consequently making it 36 trials per block. A mastery criterion of at least 90 % correct choices of comparisons was required to progress to the next stage of the experiment. If the participants did not reach this criterion, the block was repeated until the criterion was met. In this block, programmed consequences were scheduled for all comparison choices.

Maintenance of baseline trials During the maintenance component, all phases were conducted in blocks of trials. The trial types presented here were the same as the trials presented in the acquisition block. Programmed consequences for trials in a block were presented on 75 %, 25 %, and finally 0 % of trials in a block, in that order. Reduction of programmed consequences occurred as soon as a participant responded with at least 90 % accuracy on all of the trials in a block at a given level. A block at a given programmed consequence level was repeated until it produced the criterion level of responding. For each level, the trials that produced programmed consequences were randomized in a block. When the participants reached the mastery criterion on the last block with no programmed consequences, the test for emergent relations was introduced.

Test for emergence of derived relations The last block with no programmed consequences was followed by an emergent relations test block containing 180 trials. These 180 trials comprised of 36 baseline trials; 36 symmetry trials; 54 one-node trials; 36 two-node trials; and 18 three-node trials. All of the trials were randomly presented and were without programmed consequences.

For purposes of analysis, the 180-trial test block was divided into two 90-trial test blocks, with test block 1 containing trials 1–90 and test block 2 containing trials 91–180. The formation of equivalence classes was defined by the selection of the comparisons that were consistent with experimenter-defined classes on at least 90 % of the trials in the block. Immediate emergence was defined as meeting mastery on test block 1, with maintenance assessed by performances on the second test block. Delayed emergence was defined as the selection of correct comparison in at least 90 % for the trials in test block 2. Failure to form classes was defined by the selection of class indicative comparisons on less than 90 % of the trials in each test block.

Training of identity conditional discriminations As mentioned above, participants in the Id-S-MTS and the Id-6sD-MTS conditions acquired C-based identity conditional discriminations before the administration of the simultaneous protocol used to establish the ABCDE equivalence classes. For the participants in the Id-S-MTS and the Id-6sD-MTS groups, the three C stimuli were presented as trials; **C1**/<u>C1</u>-C2-C3, **C2**/C1-<u>C2</u>-C3, and **C3**/C1-C2-<u>C3</u>. Training was done in a minimum of three blocks with 100 % programmed consequences (See Table 2 for details). Three more blocks of fading of programmed consequences (75 %, 25 %, and 0 %)

Table 1 This table provides an overview of the experimental phases in the conditional discrimination training and testing

Experimental Phases	Trial Types	%Programmed Consequences	Min. # of Trials
Acquisition of baseline relations	A1B1, A2B2, A3B3,B1C1,B2C2, B3C3	100	36
All trial types presented randomly	C1D1,C2D2, C3D3, D1E1,D2E2, D3E3		
Maintenance: Thinning of programmed consequences			
	A1B1, A2B2,A3B3,B1C1, B2C2, B3C3	75	36
	C1D1, C2D2, C3D3,D1E1,D2E2, D3E3		
	A1B1, A2B2,A3B3,B1C1, B2C2, B3C3	50	36
	C1D1, C2D2,C3D3, D1E1,D2E2, D3E3		
	A1B1, A2B2, A3B3,B1C1,B2C2, B3C3	25	36
	C1D1, C2D2, C3D3,D1E1,D2E2, D3E3		
	A1B1, A2B2, A3B3,B1C1, B2C2,B3C3	0	36
	C1D1, C2D2, C3D3,D1E1,D2E2, D3E3		
Test for derived relations			
All trial types presented randomly	Baseline trials		
	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3	0	36
	C1D1, C2D2, C3D3, D1E1, D2E2, D3E3		
	Symmetry trials		
	B1A1, B2A2, B3A3, C1B1, C2B2, C3B3	0	36
	D1C1, D2C2, D3C3, E1D1, E2D2, E3D3		
	1 Node trials		
	A1C1, A2C2, A3C3, C1A1, C2A2, C3A3,		
	B1D1, B2D2, B3D3, D1B1, D2B2, D3B3,	0	54
	C1E1, C2E2, C3E3, E1C1, E2C2, E3C3,		
	2 Node trials		
	A1D1, A2D2, A3D3, D1A1, D2A2, D3A3,	0	36
	B1E1, B2E2, B3E3, E1B1, E2B2, E3B3		
	3 Node trials		
	A1E1, A2E2, A3E3, E1A1, E2A2, E3A3	0	18

were required to be completed before a test block brought the procedure to an end. Each programmed consequence lasted 1,000 ms and was followed by an inter-trial interval lasting 1,000 ms. In each block, at least 90 % correct responses were required before participants could proceed to the next stage in the experiment. Each block was repeated until the mastery criterion was attained, but if it is not attained after three blocks, the level of programmed consequences was increased to the previously used value in the next block. In the Id-6sD-MTS group, it was arranged for a fixed 6 s delay between the offset of the sample and the onset of the comparisons. Thus, with a mouse click on the sample stimulus in each trial, the sample disappeared 6 s before the onset of the comparison stimuli.

Table 2 Overview of phases in the identity simultaneous and delayed matching-to-sample training.

Experimental Phases	Trial Types	% of Programmed Consequences	Min. # of Trials
Acquisition of baseline trials (Randomized)			
	C1/**C1**-C2-C3, C2/C1-**C2**-C3, and C3/C1-C2-**C3**	100	36
Maintenance: Thinning of programmed consequences			
	C1/**C1**-C2-C3, C2/C1-**C2**-C3, and C3/C1-C2-**C3**	75	18
	C1/**C1**-C2-C3, C2/C1-**C2**-C3, and C3/C1-C2-**C3**	25	18
	C1/**C1**-C2-C3, C2/C1-**C2**-C3, and C3/C1-C2-**C3**	0	72

Results

Pre-class formation sorting performances Sorting performances for individual participants are shown in the left side of Table 3. Prior to class formation training, no participants sorted the stimulus cards into piles that corresponded to the three experimenter-defined classes. Instead, they sorted the cards into stacks from two to seven stimuli, none of which contained all cards from the experimenter-defined classes. These "zero yields" are also presented as a summary value in the leftmost bar in each cluster in Fig. 2.

Equivalence class formation Figure 2 shows the percentage of participants in each group who did and did not show class indicative performances in the pre- and post-training sorting tests, and the formation of classes during the simultaneous protocol. Each cluster of three bars is for a different experimental condition.

All but two participants maintained the same number of responses according to the experimenter-defined classes in the first and second test halves. Therefore, some showed the immediate emergence of classes and their maintenance with test block repetition, and others did not show mastery levels of responding in either block, which documented the failure of class formation.

The two exceptions, Participants 4622 and 4619, responded differently in each test block. Specifically, each showed an increase in class consistent responding from the first to second test block, from 80 to 100 % of trials in a block that were in accordance with experimenter-defined classes. These performances then showed the delayed emergence of the classes. Therefore, overall yields (class formation regardless of delay) will be used to evaluate the effects of the independent variables on class formation.

During the simultaneous protocol (middle bar per cluster), when no pre-training was used (the ABS group), a very small proportion of participants formed the equivalence classes that contained abstract stimuli only. In contrast, 80 % of participants formed the equivalence classes when the C stimuli were meaningful pictures. Thus, the inclusion of a meaningful picture as a potential class member enhanced the likelihood of class formation.

When the Id-S-MTS procedure was used to establish the C-based identity conditional discriminations, no participants formed classes. Thus, the likelihood of class formation was similar, but even lower than that found when classes were formed with no prior training. The prior training of simultaneous identity conditional relations with the C stimuli, therefore, either did not influence, or could have suppressed the likelihood of the subsequent formation of equivalence classes.

For the Id-6sD-MTS group, where the C-based identity conditional discriminations were established on a delayed basis, yields were much greater than that obtained after Id-S-MTS training. In addition, the yields approximated those produced when the classes contained meaningful picture as the C stimuli.

Fisher's Exact Test (FET) showed that the yield obtained in the PIC condition was significantly different from the yields produced by the ABS ($p=0.0001$) and the zero-delay condition ($p=0.0001$). In addition, the yields produced by the SIM and 6 s conditions were significantly different from each other (FET $p=0.011$). The difference in yields produced by the ABS and 6 s conditions approached significance by FET $p=0.057$, and was significant by Chi Square = 0.019.

Post-class formation sorting performances The rightmost bar per cluster shows the results of the sorting tests conducted after the administration of the simultaneous protocol (see the right side of Table 3). The yields in the ABS, Id-S-MTS, and Id-6sD-MTS groups were the same as those seen during the simultaneous protocol. In the PIC condition, however, all of the participants who formed classes under the simultaneous protocol continued to do so in the sorting test, and one more participant (4637) who did not show class formation in the derived relations tests subsequently did so in the sorting test. Thus, the data obtained from 39 of the 40 participants in the experiment showed perfect concordance between the performances evoked by the derived relations and the sorting tests.

Acquisition of baseline relations and class formation In addition to influencing the likelihood of equivalence class formation, the experimental conditions could also influence the acquisition of the baseline relations for the equivalence classes. This possibility was evaluated in the upper panel of Fig. 3, which depicts the median/average number of trials needed to acquire the baseline relations in each group, for participants who did and did not form classes.

Acquisition of the baseline relations was significantly faster for participants who formed classes than for those who did not, $t\ (38)=-3.861$, $p<0.05$. Across all conditions, then, acquisition speed of the baseline relations was inversely correlated with class formation.

For the ABS, PIC, and Id-6sD-MTS groups, similar rates of acquisition occurred for those who then formed classes. In addition, slower but similar rates of acquisition occurred for the participants who did not form classes. A comparison of the data in the two right most pairs of bars for participants who did not form classes, indicated that the acquisition of the baseline relations occurred more rapidly after preliminary training with a delay than without a delay. In addition, the number of trials needed to acquire the baseline relations after the preliminary establishment of the identity conditional relations was far greater than when observed after any other condition, regardless of subsequent class formation.

Table 3 Pre- and Post-Sorting Test Outcomes

Condition	Participant #	Pre experimental sorting																				
		Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3
	4610	4	0	0	1	3	5	0	2	0												
	4600	1	0	2	1	1	0	1	1	1	1	1	0	1	2	2						
	4619	2	0	1	1	0	2	1	1	0	1	3	0	0	1	2						
	4609	1	2	0	1	1	1	1	0	2	2	0	1	0	2	1						
	4616	2	1	0	1	0	2	2	1	0	0	2	1	0	1	2						
Abstract	4623	2	2	1	2	0	3	1	3	1												
	4604	3	1	0	1	0	1	1	2	2	0	2	2									
	4615	3	0	0	1	1	2	1	1	0	0	2	1	0	1	2						
	4644	4	1	0	1	1	1	0	2	2	0	1	2									
	4640	1	2	0	2	1	1	1	0	1	1	1	1	0	1	2						
	4620	3	0	2	1	1	1	1	2	1	0	2	1									
	4639	2	1	0	1	0	2	1	1	1	1	3	2									
	4621	3	1	1	1	1	1	1	3	3												
	4606	2	0	1	1	1	1	2	1	0	0	2	1	0	1	2						
C as Pics	4603	3	1	0	1	1	1	1	1	1	0	2	3									
	4618	3	1	1	1	1	1	1	3	3												
	4602	4	0	0	1	1	1	0	4	4												
	4622	3	1	0	1	1	1	1	1	0	0	2	2	0	0	2						
	4637	1	0	1	1	1	0	1	1	0	1	1	0	1	1	0	0	1	1	0	0	3
	4611	1	2	1	2	1	1	1	1	1	1	1	2									
	4613	4	0	4	1	5	1															
	4612	3	0	1	2	2	1	0	3	3												
	4624	2	1	2	2	2	1	1	2	2												
Abs C after	4605	2	0	1	3	0	0	0	3	0	0	1	2	0	1	2						
Id-6sD-MTS	4614	3	0	1	1	1	1	1	1	2	0	3	1									
	4626	3	0	0	1	2	2	1	1	2	0	2	1									
	4607	1	0	1	2	1	2	1	2	1	1	2	0	0	0	1						
	4608	3	1	0	1	0	2	1	2	3	0	2	0									
	4646	2	0	1	1	1	0	1	1	0	1	0	1	0	1	1	0	1	1	0	1	1
	4642	2	0	1	1	1	1	1	1	0	1	0	2	0	2	0	0	1	1			
	4628	2	1	0	1	0	1	2	1	0	0	1	1	0	1	2	0	1	1			
	4630	3	1	1	2	4	4															
Abs C after	4632	4	2	1	1	1	3	0	2	1												
Id-S-MTS	4629	1	0	1	2	1	0	1	1	0	1	1	1	0	2	1	0	0	2			
	4631	2	0	1	1	0	1	1	1	2	1	4	1									
	4634	4	2	1	1	3	4															
	4635	2	1	2	3	1	0	0	3	3												
	4636	2	2	1	1	1	3	2	2	1												
	4643	4	1	1	1	4	4															
	4645	2	0	1	1	1	1	2	1	0	0	1	1	0	1	1	0	1	1			

Condition	Participant #	Post experimental sorting																		ECF	Sort
		Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	Cls-3	Cls-1	Cls-2	cls-3		
	4610	5	0	0	0	5	0	0	0	5										YES	YES
	4600	3	0	0	2	0	0	0	3	0	0	2	1	0	0	4				NO	NO
	4619	5	0	0	0	5	0	0	0	5										NO	NO
	4609	2	0	1	1	0	2	1	1	1	1	2	0	0	2	1				NO	NO
	4616	1	0	5	4	0	0	0	3	0	0	2	0							NO	NO
Abstract	4623	2	1	2	2	2	1	1	2	2										NO	NO
	4604	2	1	0	3	0	1	0	4	0	0	0	4							NO	NO
	4615	2	0	2	2	2	0	1	0	3	0	3	0							NO	NO
	4644	1	0	2	3	0	1	1	1	2	0	0	4							NO	NO
	4640	2	1	0	2	0	3	1	1	1	0	2	0	0	1	1				NO	NO
	4620	5	0	0	0	5	0	0	0	5										YES	YES
	4639	5	0	0	0	5	0	0	0	5										YES	YES
	4621	5	0	0	0	5	0	0	0	5										YES	YES
	4606	5	0	0	0	5	0	0	0	5										YES	YES
C as Pics	4603	5	0	0	0	5	0	0	0	5										YES	YES
	4618	5	0	0	0	5	0	0	0	5										YES	YES
	4602	5	0	0	0	5	0	0	0	5										YES	YES
	4622	5	0	0	0	5	0	0	0	5										YES	YES
	4637	5	0	0	0	5	0	0	0	5										NO	YES
	4611	3	0	2	0	5	0	2	0	3										NO	NO
	4613	5	0	0	0	5	0	0	0	5										YES	YES
	4612	5	0	0	0	5	0	0	0	5										YES	YES
	4624	5	0	0	0	5	0	0	0	5										YES	YES
Abs C after	4605	5	0	0	0	5	0	0	0	5										YES	YES
Id-6sD-MTS	4614	5	0	0	0	5	0	0	0	5										YES	YES
	4626	5	0	0	0	5	0	0	0	5										YES	YES
	4607	2	1	0	1	1	1	2	0	1	0	3	0	0	0	3				NO	NO
	4608	3	0	0	2	0	0	0	2	1	0	3	0	0	0	2	0	0	2	NO	NO
	4646	4	0	0	1	1	0	0	4	0	0	0	5							NO	NO
	4642	5	0	0	0	4	1	0	1	4										NO	NO
	4628	3	0	0	2	0	0	0	2	0	0	2	0	0	1	1	0	0	4	NO	NO
	4630	3	0	0	2	0	0	0	2	1	0	3	0	0	0	2	0	0	2	NO	NO
Abs C after	4632	2	0	0	3	1	0	0	3	0	0	1	3	0	0	2				NO	NO
Id-S-MTS	4629	2	0	0	2	0	1	1	0	1	0	4	0	0	1	1	0	0	2	NO	NO
	4631	4	0	0	1	3	2	0	2	3										NO	NO
	4634	3	1	0	2	0	0	0	4	0	0	0	5							NO	NO
	4635	3	2	0	2	3	0	0	0	5										NO	NO
	4636	3	1	0	2	0	0	0	4	0	0	0	5							NO	NO
	4643	3	2	2	2	3	3													NO	NO
	4645	2	3	2	3	2	0	0	0	3										NO	NO

Note: The first column indicates the experimental conditions studied in the experiment. Each row indicates data for a given participant. The table consists of boxes each of which has three cells. Each cell contains information for experimenter-defined Classes 1, 2, or 3. The entries in each cell indicate the number of stimuli in each experimenter-defined class that the participant assigned to one subject-defined class. Thus, each box designates the content of a subject-defined class. Participants were separated into those who did and did not form equivalence classes (ECF) based on emergent relations test performances, as indicated by Y and N in the next to the right-most column. The right-most column indicates the presence of sorting clusters that correspond to the presence of all three experimenter-defined classes. ECF = Equivalence Class Formation, ABS = abstract stimuli, Id-S-MTS = identity simultaneous matching-to-sample, Id-6sD-MTS = identity 6 s delayed matching-to-sample, and PIC = Pictures

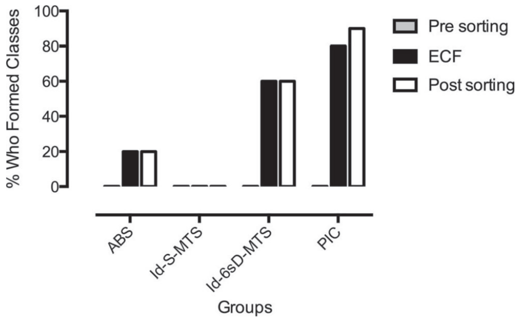

Fig. 2 Shows the percentage of participants in each gruop who did and did not show class indicative performances in the pre-and post-training sorting tests,and formed eqivanlence classes.ECF = Equivalence Class Formation,ABS = Abstrct Stimuli,Id-S-MTS = identity simultaneous matching-to-sample,Id-sD-MTS = identity six seconds delayed matching-to-sample, and PIC = Pictures

The lower panel of Fig. 3 depicts the percentage of correct trials during the emergent relations tests blocks for participants who did not form classes in each experimental condition. The percentage of errors was greater in the ABS and Id-S-MTS conditions than for the PIC and Id-6sD-MTS conditions. A one-way ANOVA showed that the Id-S-MTS and the ABS groups had a significantly higher likelihood of making errors during the derived relations tests when compared to the PIC and the Id-6sD-MTS groups ($F = 11.65$, $p = 0.0006$).

Discussion

Equivalence classes were formed by 10 % of the participants when all of the class members were abstract stimuli (ABS group), and by 80 % of participants when the middle node was a familiar picture and the other class members were abstract stimuli (PIC group). These findings replicate those reported by Fields et al. (2012), and show that the inclusion of a meaningful stimulus enhances equivalence class formation.

In addition, 60 % of participants formed equivalence classes with sets of abstract stimuli when the middle nodes had previously become members of identity conditional discriminations that were established on a delayed basis (Id-6sD-MTS group). Further, when the identity function was established with no delay, 0 % of the participants formed the equivalence classes. Thus, the delay that separated the offset of sample stimuli and the onset of the comparison stimuli in identity conditional discrimination training played a critical role in the enhancement of equivalence class formation. By implication, these results support the view that some proportion of the class-enhancing properties of meaningful stimuli can be attributed to their presumed membership in identity relations established on a delayed basis.

Fields et al. (2012) and Travis et al. (in press) have shown that likelihood of equivalence class formation increased by the prior acquisition of simultaneous and successive discriminative functions. In addition, Travis et al. (in press) showed that class enhancement was a positive linear function of the amount of pre-class formation overtraining of simple successive discriminations. The present experiment showed that the establishment of identity conditional relations on a delayed basis also enhanced the likelihood of subsequent equivalence class formation. Taken together, all of these data support the more general view that enhancement of class formation produced by the inclusion of a meaningful stimulus in that class can be accounted for by the many stimulus control functions served by the meaningful stimulus as well as, or in addition to, their connotative and denotative properties.

Effects of identity and/or delay functions The results of the present experiment demonstrated that class enhancement was directly related to the delay that separated the termination of sample stimuli and the presentation of the comparison stimuli in identity conditional relations. Thus, the enhancement effect could be due to the delay function itself, or the delay function as constrained by the context of identity conditional

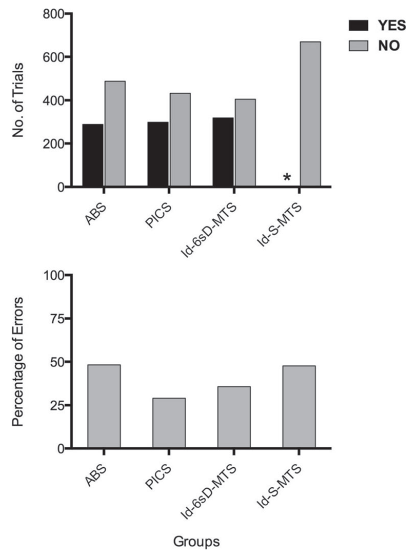

Fig. 3 The upper panel shows the averange number of trials to acquire baseline realtions in each group who did(YES) and did not (NO) respond in accordance with stimulus equivalence.The lower panel shows the percentage of error during the test for the partricipants who did not respond in accordance with stimulus equivalence.ABS = abstract stimuli,Id-S-MTS = identity simultaneous matching-to-sampke,Id-6sD-MTS = identity six second delayed matching-to-sample, and PIC = Pictures. The * indicates the absence of data

discriminations. The relative influence of the type of conditional relation alone, however, cannot be discerned from the present experiment.

The isolated and interactive effects of these two variables can be determined with additional research in which delay value and type of conditional relations are varied in a factorial manner. Specifically, conditional relations can be identity based, where the samples and positive comparisons are the same (Z→Z), or arbitrarily based where the samples and positive comparisons are perceptually disparate (Z→X). Each of these relations can be established using simultaneous or delayed matching trial formats. If the same delay effects are found with identity and arbitrary conditional relations, the delay function would be responsible for class enhancement and not type of conditional relation. If different delay effects on class enhancement were to be found with the two types of conditional relation, both delay and type of conditional relation would be responsible for class enhancement. The validity of either of these conclusions awaits the conduct of such an experiment. In the present experiment, the abstract stimulus that acquired conditional control before class formation was subsequently used as the middle node in three-node five-member equivalence classes. Recent research (e.g., Arntzen, 2004; Fields et al., 2012) has shown that the position of a meaningful stimulus in an equivalence class, as well as its temporal order of inclusion in training, substantially influence class enhancement of stimuli. Thus it is possible that abstract stimuli that acquire identity functions can have a similar effect. The evaluation of these suppositions awaits future research.

Quantification of the delay effect The present experiment found that a 6 s delay had a major effect on class enhancement, while no delay did not produce any class enhancement. To what extent then will the likelihood and magnitude of class enhancement depend on the duration of the delay interval? Experiments on working memory typically find that delays greater than 3 s result in greater recall (e.g., Baddeley 2007), presumably because participants have time to encode stimuli and imbed their representations in long term memory for use in recall. By implication, enhancement should be substantial for delays of as little as 3 s and then decline markedly below that value. Thus, the effects of the 0 and 6 s delays would be placed in a parametric context that also make contact with the mechanisms of memory and relate them to the likelihood of equivalence class formation.

As noted in the results, after the establishment of simultaneous identity relations in preliminary training, no participants formed equivalence classes. Indeed, that yield was even lower than the already low yield obtained in the ABS condition (0 % vs. 20 % yields, respectively). The fact that none of the participants had a history of forming simultaneous identity relations does not mean that these individuals never responded correctly during the derived relations tests. On average, they selected class consistent comparison stimuli on 52 % of the derived relations probes. Furthermore, likelihood of errors in the derived relations tests were greater after the formation of identity relations on a simultaneous instead of a delayed basis. Thus, the establishment of identity relations with the C stimuli in the simultaneous condition had an effect both on the speed of acquisition of the baseline condition discriminations and the errors made during the derived relations tests.

The apparent suppression of yield might have been driven in the following manner. When forming simultaneous identify relations, a sample stimulus is presented with one comparison that is identical to the sample, and another that is not. Reinforcement depends on selection of the comparison that is the same as the sample stimulus rather than the selection of the comparison that differs from the sample stimulus. In contrast, the baseline relations for the equivalence classes are arbitrary conditional relations where both comparisons differ from the prevailing sample stimulus; thus, reinforcement depends on the selection of a comparison that differs from a sample stimulus. This stimulus control repertoire then is in conflict with the stimulus control repertoire established during identity training. Overcoming that repertoire would be reflected in many more trials than would be needed to form the baseline relations for the classes, as indicated by the trials to acquisition data. In addition, the processing activity involved in overcoming the identity training might have interfered with attending to the relations among the stimuli in different baseline relations, which would obviate the emergence of derived relations, and result in the absence of equivalence class formation.

The effects of delay and coding Typical studies show slower or less likely formation of conditional discriminations with increasing delay (White 2013). In the present experiment, the opposite occurred with the acquisition of the baseline relations. In addition, the likelihood of equivalence class formation was a direct function of delay duration in pre-class formation identity conditional discrimination training. Both of these findings may be related to the emergence of coding (Urcuioli 2013) or mediating behavior in the delay interval. As has been argued by Arntzen (2006), the DMTS procedure encourages the emergence of mediating behavior that bridges the gap between sample offset and comparison onset and leads to the more likely selection of the correct comparisons in DMTS trials. In the context of the present experiment, such a repertoire could have been induced during the establishment of the C-based identity conditional discriminations in the delay condition, after which they would generalize to the emergent relations tests, where the mediating behavior would enhance the coding of the sample stimuli in the derived relations test trials set and facilitate the selection of a comparison from the same class. That possibility would also increase the likelihood of class formation. By contrast, when establishing the C-based identity conditional discriminations in the simultaneous matching-to-sample context, both sample and comparisons were presented at the same time, so there is no need for response mediation to solve the identity problem. Because a response mediation repertoire did not occur during identity training, that repertoire was not available to generalize to the stimuli in the emergent relations tests, and enhance the emergence of the classes.

Connotative properties and conditional discriminations Traditionally, the class-enhancing effect of including a meaningful stimulus as a member of a to-be-formed equivalence class has been attributed to the connotative properties of the meaningful stimulus. Connotative property is defined by the stimuli that have come to be associated with the meaningful stimulus, i.e., the stimulus-stimulus relations of which the meaningful stimulus is a member. In such an account, it is assumed that the connotative property has been established pre-experimentally, and by procedures unknown to the present researchers.

In the present experiment, a meaningless stimulus (C) became a member of the simplest form of stimulus-stimulus relation — an identity conditional discrimination (C→C) — by an explicitly defined pre-class formation training procedure. It follows, then, that the C stimulus acquired a minimal connotative property. Thus, the enhancement of class formation by the inclusion of a nominally meaningless stimulus that previously acquired a delayed identity function is akin to saying the enhancement of class formation can be attributed, in part, to an explicitly produced connotative property of that stimulus. Conversely, the class enhancement effect can be attributed, in part, to the procedures used to establish the identity conditional discrimination established on a delayed basis. Regardless of the phraseology, the results of the present experiment extend our knowledge of procedures that enhance the formation of equivalence classes when training and testing are conducted using the simultaneous protocol, a protocol that typically does not support high likelihoods of equivalence class formation, and also provides an account of the behavioral stimulus control functions served by meaningful stimuli that are partially responsible for the enhancement of equivalence class formation that contain such stimuli.

Sorting performances After exposure to the simultaneous protocol, the participants who formed classes then showed class indicative performances in the sorting test, but not so for those who did not form classes. These results documented the maintenance of the classes in a different test format, replicated Fields et al. (in press), and complemented related findings reported by Bortoloti and de Rose (2009, 2012). This concordance of tests results in the present experiment was obtained under all experimental conditions. Therefore, prior identity conditional discrimination training and the inclusion of pictorial stimuli in equivalence classes did not influence the concordance of the two test performances.

Summary The inclusion of a meaningful stimulus in a set of abstract stimuli enhanced the likelihood of forming an equivalence class with the set. A similar effect was obtained when classes were formed with all abstract stimuli after one of them came to function as a member of an identity conditional discrimination established on a delayed basis. No enhancement was obtained when the identity relation was established on a simultaneous basis. By implication, the enhancement of class formation by the inclusion of a meaningful stimulus can be driven by the presumed delayed identity function served by the meaningful stimulus.

Conflict of Interest There is no conflict of interest to declare concerning the three authors.

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Study 5

Enhancing Responding in Accordance with Equivalence by the Delayed and Relational Properties of Meaningful Stimuli

Erik Arntzen, Richard K. Nartey and Lanny Fields

Arntzen, E., Nartey, R.K., & Fields, L. (submitted). Enhancing Responding in Accordance with Stimulus Equivalence by the Delayed and Relational Properties of Meaningful Stimuli

Enhancing Responding in Accordance with Stimulus Equivalence by the Delayed and Relational Properties of Meaningful Stimuli

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Abstract

The present experiment investigated how equivalence class formation was enhanced by the inclusion of one abstract stimulus that had acquired an identity or arbitrary conditional discriminative function on a simultaneous or delayed basis, prior to the establishment of the classes. Sixty college students were trained to form three 3-node 5-member equivalence classes (A→B→C→D→E) under the simultaneous protocol. For participants in the ABS group, all of the stimuli used were abstract shapes, while in the PIC group, the C stimuli were pictures and the A, B, D, and E stimuli were abstract shapes. Before class formation training, participants in the Id-S-MTS and Id-6sD-MTS groups formed identity conditional discriminations with the C stimuli using simultaneous or 6 s delayed matching-to-sample procedures, respectively. In the Arb-S-MTS and Arb-6sD-MTS groups, prior to class formation, arbitrary conditional discriminations were formed between the C and X stimuli using simultaneous or 6 s delayed matching-to-sample procedures, respectively. Classes were formed by 80% and 0% of participants in the PIC and ABS groups, respectively. Yields were a direct function of delay duration, regardless of type of conditional relation formed prior to equivalence class training. For each delay, yield was greater after forming arbitrary relations than identity relations. No conditions produced yields that matched those obtained when the classes contained a meaningful stimulus. Thus, class enhancement by meaningful stimuli can be accounted for in part by their identity and arbitrary relational functions, and their associated delays. Finally, some “errors” during testing was not reflective of random responding; rather, it reflected subject-defined relational control instead of experimenter defined relational control of behavior.

Key words: Stimulus equivalence, identity conditional relations, arbitrary conditional relations, linear series training structure, concurrent, college students

Denotative properties (defining features) and connotative properties (emotive and judgmental features) has traditionally been used to define meaningfulness of stimuli. Further, depth of meaningfulness can be indexed by the number of denotative and connotative terms with which a stimulus or term is associated. A meaningful stimulus can influence the learning of new relations among stimuli (Arntzen, 2004). The inclusion of a meaningful stimulus in a set of otherwise meaningless stimuli can enhance the likelihood of forming an equivalence class amongst them. For instance, to most members of an English speaking society, the six words for the numeral 9 as written in Japanese, Cyrillic, Chinese, Urdu, Korean, and Arabic would be meaningless and would not occasion the mutual selection of each other. After training conditional discriminations required for the testing of equivalence class formation, there is a likelihood that the stimuli will function interchangeably and thus, would be acting as members of an equivalence class. However, the likelihood of class formation would be increased by the inclusion of the English word NINE, a meaningful stimulus for this particular community, as a member of the set of the to-be-formed class.

The simultaneous protocol has been used to study the formation of equivalence classes in many experiments. It involves the training of all baseline relations to mastery level after which all derived relations probes are tested together in the same test block. The formation of equivalence classes involving meaningless stimuli under the simultaneous protocol has been found to be less likely (e.g., Arntzen, Grondahl, et al., 2010; Buffington, Fields, & Adams, 1997) and thus, makes that protocol a sensitive measure of variables that can enhance class formation.

Findings have shown that there is lower probability of class formation if the meaningful stimuli had connotatively contradictory valences (Grehan, 1998; Leslie et al., 1993; Plaud, 1995; Watt, Keenan, Barnes, & Cairns, 1991). On the other hand, there is a very high likelihood of class formation among stimuli that have compatible connotative valences (e.g., Dickins et al., 1993).When only one of the stimuli in the set was meaningful (e.g., a picture) and the remaining stimuli were meaningless, classes have been formed by an intermediate percentage of participants (e.g., Arntzen & Lian, 2010; Fields et al., 2012). These class enhancement effects are typically attributed to the connotative/emotive properties of the meaningful stimulus, the stimuli with which the stimulus is related and the respondents and operants occasioned by the stimulus (Travis et al., 2014).

Also, the class-enhancing properties of meaningful stimuli could be due to their acquired behavioral stimulus control functions (Fields et al., 2012; Tyndall et al., 2004). For example, a meaningful stimulus can function as a discriminative stimulus for many responses. It can also occasion the selection of another stimulus such as itself (as in an identity conditional relation) or a printed definitional statement or a printed statement of its emotive content (as is in an arbitrary conditional relation). A meaningful stimulus can also act as a member of an equivalence class or a naturally occurring category and be used interchangeably with many other stimuli. Thus, some proportion of the class enhancing effect of a meaningful stimulus could be accounted for by the presence of any combination of these acquired stimulus control repertoires

Initial support for this view was provided by Fields et al. (2012). Using meaningless stimuli designated as A, B, C, D, and E, the experiment began with the establishment of the C stimuli as discriminanda in simple successive and simultaneous discrimination paradigms. Thereafter, ABCDE equivalence classes were formed by 50% of participants. In contrast, the same classes were formed by 0% of participants for whom the C stimuli had no discrimination training history, and by 80% of participants when the classes contained meaningful and familiar pictures as the C stimuli. Using the same design, Travis et al. (2014) found that the establishment of simultaneous discriminations alone, and increases in the overtraining of successive discriminations increased in subsequent likelihood of class formation. These experiments demonstrated that a portion of the increase in class formation could be accounted for the acquisition of simple discriminative functions by a meaningless stimulus that was then used as a member of the to-be-formed class. At most, the denotative and/or connotative properties of the meaningful stimuli could account for the difference in yield produced when the ABCDE classes contained the meaningful stimulus and when the class contained a C stimulus that had acquired discriminative functions.

As noted above, meaningful stimuli also serve identity or arbitrary conditional discriminative functions. In an identity conditional relation, an individual is presented with a range of sample stimuli along with a set of comparison stimuli, one of which is identical to the sample stimulus and the selection of that comparison would document the presence of an identity relation. Arntzen et al. (2014b) showed that the likelihood of class formation was not enhanced by the pre class formation of identity relations using the C stimuli where the sample and comparison stimuli are concurrently presented (a simultaneous identity relation). In contrast, equivalence class formation was enhanced by the pre-class C-based identity relation was established on a delayed basis. Specifically, on each trial, sample stimuli were presented and were then eliminated by the occurrence of an observing response. Six seconds later, the set of comparison stimuli was presented, and the selection of the correct comparison in the absence of the sample led to reinforcement. Thus, class-enhancement was directly related to the delay that separated the termination of sample stimuli and the presentation of the comparison stimuli during pre-class formation of identity conditional relations. This finding, however, could have been due to the delay itself, or the delay constrained by the context of identity conditional discrimination, or the combination of both operations. The data collected in that experiment, however, did not provide the opportunity for making that separation.

These possibilities were explored in the present 6-group experiment. All participants attempted to form three 3-node 5-member equivalence classes (A→B→C→D→E) using the simultaneous protocol. In the PIC group, the C stimuli were pictures and the A, B, D, and E stimuli were abstract shapes. In the ABS group, all of the stimuli were abstract shapes. In the Id-S-MTS and Id-6sD-MTS groups, prior to class formation, identity conditional discriminations were formed with the C stimuli (C→C) using the simultaneous or 6 s delayed matching-to-sample procedures, respectively. In the Arb-S-MTS and Arb-6sD-MTS groups, prior to class formation, arbitrary conditional discriminations were formed with the C stimuli (C→X) using simultaneous or 6 s delayed matching-to-sample procedures, respectively. The yields obtained in the ABS and PIC groups assessed the effects of no prior training history (ABS) and the inclusion of a meaningful stimulus (PIC) on equivalence class formation. The other four conditions constituted a factorial design that showed how the prior establishments of C-based identity or arbitrary conditional relations (relational type) under conditions of simultaneous or 6s delay (delay) influenced the likelihood of forming equivalence classes that contained the abstract C stimuli.

Method

Participants

Sixty students at the University of Ghana participated in the experiment. Twenty-six males and 34 females participated voluntarily in this study. They were between the ages of 19 and 28 years (*M* = 21.5, *SD* = 1.5) and were unfamiliar with stimulus equivalence research and methodology. Participants were randomly assigned to one of six experimental conditions ten participants in each group.

Apparatus

Setting. The experiment took place in a lab at the Department of Psychology at the University of Ghana that measured approximately 5m x 5m and was furnished with tables and chairs.

Hardware. An HP Compaq nc6320 laptop computer with a 1828 MHz Intel Centrino® processor, and had a screen with a 16.8 in. diagonal length and a 16 × 9 horizontal-to-vertical ratio was used to conduct the experiment. Participants used an external mouse to control the position of the cursor throughout the experiment.

Software. An MTS software made by Psych Fusion Software in collaboration with first author was used for the training and testing of conditional discriminations for all participants. The software controlled the presentation of all stimuli and also made recordings of data including number of training trials, reaction time to sample and comparison stimuli, the duration of the experiment, correct/incorrect comparison choices as well as a summary of participants' performances in the test for emergent relations.

Stimuli. Figure 1 shows the stimulus sets used in the experiment. The top two sections of the figure show stimuli used as members of the equivalence classes, which consist of 15 abstract and the 3 familiar picture-stimuli. The bottom section shows the stimuli used during arbitrary matching training. The abstract stimuli were displayed in black and the picture stimuli in colors, both on a white background.

Procedure

The experiment began with the presentation of an informed consent form which was to be read by the participants. The form stated that participants were about to participate in an experiment in the field of behavior analysis that will last approximately one and half-hours and that, data collected would be anonymous. They were also informed that they were free to withdraw from the experiment at any time without any negative consequences. After reading, those who agreed by signing of the forms began the experimental protocol.

After identity and arbitrary training, if required (see below), participants remained seated behind the computer and were presented with the following instructions on the computer screen:

> "In a moment a stimulus will appear in the middle of the screen. Click on this by using the computer mouse. Three stimuli will then appear in three corners of the screen. Choose one of them by clicking on it with the mouse. If you choose the stimulus we have defined as correct, words like "very good", "excellent", and so on will appear on the screen. If you press a wrong stimulus, the word "wrong" will appear on the screen. At the bottom of the screen, the number of correct responses you have made will be counted. During some stages of the experiment, the computer will NOT tell you if your choices are correct or wrong. Please do your best to get everything right. Thank you and good luck!"

No further instructions were given before and after the experiment started.

Participants were trained to form equivalence classes under the simultaneous protocol. Each trial began with the presentation of the sample stimulus in the middle of the screen. Mouse clicking on the sample stimulus was immediately followed by the presentation of the three comparison stimuli at three of the corners of the screen, while the sample stimulus still remained on the screen. Correct comparison choices resulted in the removal of the sample and comparisons stimuli and the production of the words *correct*, *very good*, *super*, or *excellent* on the screen. Wrong comparison choices produced the word *wrong* on the screen. If a programmed consequence followed a selection response, it was displayed in the middle of the screen for 1,000ms. Termination of the programmed consequences message was followed with a 500ms inter-trial interval. Between trials, the mouse cursor was returned to the center of the screen.

Training of identity and arbitrary conditional relations

Participants in the Id-S-MTS and the Id-6sD-MTS conditions acquired C-based identity conditional discriminations before the administration of the simultaneous protocol used to establish the ABCDE equivalence classes. For the participants in the Id-S-MTS and the Id-6sD-MTS groups, the three C stimuli were presented as trials; **C1**/C1-C2-C3, **C2**/C1-C2-C3, and **C3**/C1-C2-C3. Training was done in a minimum of 3 blocks with 100% programmed consequences (See Table 2 for details). Three more blocks of fading of programmed consequences (75%, 25%, and 0%) were required to be completed before a test block brought the procedure to an end. Each programmed consequence lasted 1,000 ms and was followed by a 1,000 ms inter-trial interval. In each block, at least 90% correct responses were required before participants could proceed to the next stage in the experiment. Each block was repeated until the mastery criterion was attained, but if it is not attained after 3 blocks, the level of programmed consequences was increased to the previously used value in the next block.

In the Id-6sD-MTS group, all of the training parameters were the same as those used to establish the identity conditional relations with the following exception. Each trial began with the presentation of the sample stimulus, the mouse-click on the sample stimulus (the observing response) terminated the sample, and initiated a fixed 6s delay for the presentation of the comparison stimuli.

Participants in the Arb-S-MTS and the Arb-6sD-MTS conditions acquired the arbitrary C-based conditional discriminations (C→X) before the administration of the simultaneous protocol used to establish the ABCDE equivalence classes. For the participants in the Id-S-MTS and the Id-6sD-MTS groups, the three C stimuli were presented as trials; **C1**/X1-X2-X3, **C2**/ X1-X2-X3, and **C3**/ X1-X2-X3. Again, the training parameters were the same as those used to establish the identity conditional relations.

Acquisition and maintenance of baseline conditional relations. All baseline conditional discriminations were trained and tested under the simultaneous protocol (Buffington et al., 1997).Thus, all baseline relations were first trained before a test for all derived relations were presented. The trials were presented concurrently using a linear series training structure. Thus, as shown in Table 1, all trial representations: **A1**/<u>B1</u>-B2-B3, **A2**/B1-<u>B2</u>-B3, **A3**/B1-B2-<u>B3</u>, **B1**/<u>C1</u>-C2-C3, **B2**/C1-<u>C2</u>-C3, **B3**/C1-C2-<u>C3</u>, **C1**/<u>D1</u>-D2-D3, **C2**/D1-<u>D2</u>-D3, **C3**/D1-D2-<u>D3</u>, **D1**/<u>E1</u>-E2-E3, **D2**/E1-<u>E2</u>-E3, and **D3**/E1-E2-<u>E3</u> were presented randomly from the first training block.. For each trial representation, the first stimulus was the sample and the following three were the comparison stimuli, while the underlined one was the correct comparison. All 12 trial types were presented three times each in each training block, consequently creating 36-trial blocks. When participants satisfied the mastery criterion (the selection of correct comparisons on at least 90% of the trials in a block), they progressed to the next stage of the experiment. Failure to reach the mastery criterion meant the block was repeated until the criterion was met. During acquisition, all comparison choices produced programmed consequences.

Following the acquisition of the baseline conditional relations, the maintenance of the relations were assessed in four blocks of reduced programmed consequences. The percentage of trials that produced programmed consequences for trials in a block were reduced to 75%, 50%, 25%, and finally 0%. A block at a given programmed consequence level was repeated until it produced selection to the mastery criterion. For each level, the trials that produced programmed consequences were randomized in a block. Responding to the mastery criterion on the last block with no programmed consequences signaled the end of the training of the baseline relations.

Emergence of derived relations. The last block after the successful training of the baseline relations was the emergent relations test block that contained 180 trials: 36 baseline trials; 36 symmetry trials; 54 one-node trials; 36 two-node trials; and 18 three-node trials. All of the trials were randomly presented and were without programmed consequences. The test block was divided into two halves called test blocks 1 and 2, respectively. Equivalence class formation was defined by the selection of the comparisons that were consistent with experimenter-defined classes on at least 90% of the trials in one of the test blocks. Mastery in the first test block defines the immediate emergence of the equivalence classes while the second test block assesses maintenance of the emergent classes. Following failure in the first test block, mastery in the second test block documents the delayed emergence of the equivalence classes. Failure of class formation was defined by the selection of class indicative comparisons on less than 90% of the trials in both of the test blocks.

Results

Baseline Relations

Acquisition speed. The upper panel of Figure 2 shows how the acquisition of the baseline relations for the equivalence classes was influenced by the various pre class formation procedures or by a set of baseline relations that included a meaningful stimulus. For each condition, data were divided between participants who did and did not form classes. Acquisition of the baseline relations was not significantly different for participants who did and did not form classes, as confirmed by the results of a point biserial correlation analysis, (r_{pb}) = -174, p =.18. Thus, the speed of baseline acquisition did not predict likelihood of class formation.

For the participants who formed equivalence classes, no systematic differences in speed of baseline acquisition were observed for participants in the pre-training groups, F (3, 36) = 2.52, p = .074. For participants who did not form classes, acquisition speed also did not vary systematically across the four groups. For the Id-6s-SMTS, Arb-SMTS, and Arb 6s-DMTS conditions, speed of acquisition was faster for those who went on to form classes than for those who did not, t (28) = -2.114, p =.04.

For participants who formed classes, similar and faster rates of acquisition occurred for the two delay conditions (ID-6sD-MTS and ARB-6sD-MTS) relative to the remaining groups. Thus, the acquisition of the baseline relations occurred more rapidly after preliminary training with a delay than without a delay.

Error likelihood. The bottom panel of Figure 2 indicates the percentage of errors made during the acquisition of the baseline relations for each condition and for participants who did and did not form equivalence classes. Similar error rates across conditions for those who formed classes. Similar error rates across conditions for those who did not form classes. Higher error rates for those who did not form classes than for those who did form classes. However, this trend was not statistically significant, $t\ (58) = -1.512$, $p = .136$.

Equivalence Class Formation

In the present experiment, 20 participants formed classes, of whom 18 did so on an immediate basis by responding at mastery in the first test block and maintaining that mastery level of responding in the second test block. The two remaining participants (one each in the PIC and Id-S-MTS conditions) showed class formation on a delayed basis (sub-mastery performances in test block 1 and mastery levels of responding in test block 2). To assess the effect of the pre-training condition on likelihood of equivalence class formation in each condition, we included participants who formed classes regardless of delay, which will be referred to as overall yield.

The percentage of participants who formed classes in each condition is depicted in Figure 4. The single bars represent the yields obtained under the two reference conditions (ABS and PIC), and the two paired bars represent the effects of delay that separates the sample and comparison stimuli while establishing the C-based identity relations (C→C) or arbitrary relations (C→X) during pre-class formation conditional discrimination training.

No participants formed classes in the ABS condition: when the C stimuli did not acquire any conditional discriminative function prior to the administration of the protocol used to establish the ABCDE equivalence classes. In contrast, a high proportion of participants formed the equivalence classes when the C stimulus was a meaningful picture. The difference in these yields was significant, χ^2 (1) = 10.769, p = .001.

When the yields in the four pre-training conditions (the two paired bars) were compared to the yield produced in the ABS condition, all four produced yields that were greater than that observed in the ABS condition. For these conditions, the prior establishment of conditional discriminative functions for the abstract C stimulus imparted a class-enhancing property to that stimulus.

When the yields in the four pre-training conditions were compared to the yield obtained in the PIC condition, all four produced yields that were less than that observed when the C member of the class was a meaningful stimulus. Thus, the class enhancing effect pre-class formation establishment of C-based identity or arbitrary conditional relations with or without delay did not match that produced by the inclusion of a meaningful stimulus as the C member of an equivalence class.

Of primary interest, the results show how the likelihood of equivalence class formation was influenced separately and together by delay and type of conditional relation established by pre-class formation C-based conditional discrimination training. With regard to delay, the likelihood of equivalence class formation was a direct function of the delay that separated the sample offset and comparison onset during pre-class formation conditional discrimination training. Regardless of type of conditional relation established prior to class formation (identity or arbitrary), the increase in delay produced the same 30% increment in likelihood of equivalence class formation. The overall effect of delay was indexed by averaging the data for both types of conditional relations. When done, yield increased from 15% under the 0s delay condition to 45% under the 6s delay condition, a difference that was statistically significant, χ^2 (1) = 6.144, p = .013

The effect of type of relation on class enhancement was documented by viewing the separation in the separation in yields obtained for each delay. The yields obtained after the formation of arbitrary conditional relations was 10% higher than those obtained after the formation of the identity conditional relations. This trend, however, was not statistically significant.

To summarize, the formation of equivalence classes was enhanced by the pre-class establishment of identity or arbitrary conditional relations with the abstract C stimuli. These conditional relations were established on a simultaneous or a delayed MTS basis. The likelihood of equivalence class formation increased by 30% with an increase in delay, and increased by 10% by forming arbitrary relations instead of identity relations. While both delay and relational type influenced class enhancement, delay had a larger effect than did type of conditional relation.

Analysis of Response Parameters

Participant-defined emergent relations. When a participant does not respond in accordance with the experimenter-defined equivalence classes, selections across various derived relations probes could be unsystematic with regard to the experimenter-defined classes, or they could be participant-defined conditional relations that consist of stimuli drawn from different experimenter defined classes, such as C2-D3 or A1-E2. These outcomes are illustrated in Table 4, which include the number of participant-defined relations observed during the derived relations tests blocks. To qualify as a subject-defined relation, it had to occur on three occasions during the test. A cross class configuration that was repeated fewer than the three times was not considered to be a participant-defined relation. To illustrate, in the Arb-DMTS condition, Participant

4301shows quite a different response pattern than the experimenter-defined classes, with 26 participant-defined relations. For persons who do not form classes, then, the failure to respond in a manner that reflected control by the experimenter-defined classes does not imply that responding was essentially random. While that may be so in some instances, in other cases (those indicated in Table 4), the performances reflected relational control of responding but the content of the relations differed from that defined by the experimenter-defined classes.

Response Speed. Figure 4 shows speed of responding to the last five baseline trials at the end of training, and also for the first five trials during the first half and the last half of the emergent relations tests. These data were further divided into those obtained for participants who did and did not form classes (upper and lower panels). In addition data were presented for trials that evoked correct responses (selection of comparison stimuli from the same class as the prevailing sample stimulus) and those that evoked incorrect responses (selection of comparison stimuli from a class other than that from the prevailing sample stimulus). Data were averaged across participants and groups because we did not see any systematic effects of preliminary training or of the inclusion of a meaningful stimulus as a class member.

When considering the participants who formed classes (upper panel), at the end of baseline training, response speed was greater on trials that produced correct selections than incorrect selections. In the first test block, response speed was much slower for the trials that produced correct selections compared to that produced by the baseline trials, whereas response speed for trials that produced incorrect selections was similar for the baseline trials that produced incorrect selections. In the second test block, response speed for trials that produced correct selections was the same as that seen at the end of training and was much faster than that seen in the first test block. In contrast, response speed for trials that produced incorrect selections was much slower than that seen for trials that produced correct selections, and was also slower than that produced by the baseline trials that produced incorrect selections at the end of baseline training as well as in the first test block.

When considering the participants who did not form classes (lower panel), the same general patterns of response speed were obtained. The only difference was that higher response speeds were produced by baseline trials and emergent relations test trials that evoked correct selections.

Discussion

None of the participants responded in accordance with stimulus equivalence (immediate and delayed emergence) when all of the class members were abstract stimuli (ABS group), and by 80% of participants when the middle node was a meaningful picture and the other class members were abstract stimuli (PIC group). This finding is similar in extent to those reported in other experiments that used similar design parameters as Fields et al. (2012). The results of the present experiment also demonstrated that class enhancement was directly related to the delay that separated the termination of sample stimuli and the presentation of the comparison stimuli in identity and arbitrary conditional relations that were established prior to class formation. In addition, none of the pre class formation operations enhanced class formation as much as the inclusion of a meaningful stimulus in the to-be-formed class. The enhancement of class formation was influenced more by the delay that separated sample and comparison stimuli in the conditional relations than by the type of relations established with the C stimuli prior to class formation. Finally, the commonality of the slopes of the functions indicated that the two training variables acted in an additive, rather than in an interactive, fashion to enhance class formation.

Link to prior research. A prior experiment (Arntzen et al., 2014b) showed that an increase in delay also resulted in the enhancement of equivalence class formation when the pre class formation C based identity relations were established prior to class formation. Because that experiment did not explore the effect of delay using another type of conditional relation (i.e., arbitrary instead of identity), the experiment could not make clear whether the delay effect on class enhancement was limited to prior formation of identity relations alone, or whether it was a more general effect. The present experiment addressed that issue and demonstrated that increases in delay had similar class enhancing effects regardless of the type of relation that was established prior to class formation training.

Effect of delay and linkage to working memory. The present experiment found that a 6 second delay produced a large effect on class enhancement. When working memory has been studied, delays greater than 3 s maximized accuracy of recall (e.g., Baddeley, 2007). Although different preparations were used in the recall study and in the present experiments, the effects of the 6 s delay are consistent across experiments. By implication, enhancement of class formation should also be substantial for delays as small as 3 s and then should decline below that value. Finally, it is possible that delays in excess of 6 seconds might further increase likelihood of class formation to a level that more closely approximates those obtained by the inclusion of a meaningful stimulus as the C-members of an equivalence class. Additional research will be needed to assess these predictions.

Generality influenced by structural variables in classes. Arntzen (2004) and Fields et al. (2012) found that the position of a meaningful stimulus in the structure of an equivalence class as well as its temporal order of inclusion in training both influenced the enhancement of class formation. In the present experiment, the abstract stimuli that acquired conditional control before class formation were then used as the middle nodes in 3-node 5-member equivalence classes. Thus, it is possible that the class-enhancing effects noted in the present experiment might also interact with the variables noted above. Evaluation of these suppositions awaits future research.

The effects of delay and coding. The likelihood of equivalence class formation was a direct function of delay duration that characterized the pre-class establishment of C-based identity or arbitrary conditional relations. Previously Arntzen (2006) argued that the DMTS procedure could incite the emergence of mediating behavior that bridges the gap between sample offset and comparison onset during the training of the baseline relations that can then generalize to and increase the selection of correct comparisons in the derived relations probes that track the emergence of equivalence classes. This view is consistent with the emergence of coding or mediating behavior described by Urcuioli (2013). By contrast, when establishing the C-based conditional relations on a simultaneous basis, because the sample and comparisons were concurrently present at the same time, the establishment of coding or response mediation is not needed to solve the identity problem. Since a coding or response mediation repertoire was not available to generalize to the stimuli in the emergent relations tests, the conditional relations established on a concurrent basis did not enhance equivalence class formation.

The other major finding of the present experiment was that the prior establishment of an arbitrary conditional relation enhanced subsequently class formation more than the prior establishment of an identity relation. If coding or mediated responding is used to account for these finding, it implies that these bridging behaviors would be more likely to occur during the formation of arbitrary conditional relations rather than identity relations.

Class Enhancement by the Stimulus Control Functions of Meaningful Stimuli. Fields et al. (2012) and Travis et al. (2014) have shown that likelihood of equivalence class formation increased by the prior acquisition of simultaneous and successive discriminative functions. In addition, Travis et al. (2014) showed that class enhancement was a positive function of the amount of pre class formation overtraining of simple successive discriminations. The present experiment showed that the establishment of identity or arbitrary conditional relations on a delayed basis also enhanced the likelihood of subsequent equivalence class formation. Taken together, all of these data support the more general view that enhancement of class formation produced by the inclusion of a meaningful stimulus in that class can be accounted for by an increasing number of stimulus control functions served by the meaningful stimulus, that include simple simultaneous and successive discriminations, and not identity and arbitrary conditional relations formed on a delayed basis.

In a number of cases, likelihood of class formation when the class included a meaningful stimulus was not matched by the inclusion of an abstract stimulus that had acquired some stimulus control function. Under such conditions, it is possible that that the difference in yields produced by pre class formation conditional discrimination training and that produced by the inclusion of a meaningful stimulus could be attributed to the connotative properties of the meaningful stimuli. It could, however, also be attributed to some of the functional training parameters (e.g., overtraining) or position of the stimulus in the nodal structure the class itself,

Experimenter-defined vs. participant-defined classes. The source of stimulus control that is a determinant of a participant's behavior is sometimes not identical to that intended by the experimenter. Each source of stimulus control has been called a "stimulus control topography" (McIlvane & Dube, 1992). Thus, for the participants listed in Table 4, their performances in the equivalence tests that were inconsistent with the experimenter defined contingencies (one stimulus control topography) but also occurred on a consistent basis were controlled by some relations among the stimuli that differed from the experimenter defined classes (another stimulus control topography). These competing stimulus control topographies or the lack of stimulus control coherence (McIlvane & Dube, 2003) could ultimately lead to the formation of participant-defined classes and failure in the test for derived relations.

Response speed. Data on the speed of responding replicate previous studies (Arntzen et al., 2011; Arntzen & Hansen, 2011). Specifically, speed of responding decreased in the first half of testing compared to the speed during the baseline training and then became faster in the last half of testing. This initial slowing down of response speed could be due to the fact that participants were exposed to novel trials for the first time in the first half of the test, while the subsequent increase in response speed could be attributed to gained familiarity with the test trials in the second half of the test.

Furthermore, speed was much faster for correct responses than for incorrect responses. This was even more pronounced for participants who formed equivalence classes than those who did not. This disparity could reflect the influence of only one stimulus control topography in the trials that produced correct responding (thus high speed), and the influence of a variety of stimulus control topographies on those trials that produced incorrect responses (low response speed). I.e., the slow response speed is reflective of an essential conflict among many controlling stimulus control topographies, where one that is not consistent with the experimenter defined topography is stronger than the latter.

Summary. The main findings in the present experiment were that a set of abstract stimuli did not produce equivalence class formation, while including a meaningful stimulus in the set increased the formation of equivalence classes. Furthermore, when we pre-trained one member in a class with identity or arbitrary delayed matching-to-sample, it also increased responding in accordance with stimulus equivalence. In contrast when this pre-training was arranged as simultaneous matching-to-sample either identity or arbitrary matching, less enhancement was observed. The inference to make of these findings is that equivalence class formation may increase by the inclusion of a meaningful stimulus and by delayed relational functions.

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Table 1.*This table provides an overview of the experimental phases in the conditional discrimination training and testing.*

Experimental Phases	Trial Types	%Programmed Consequences	Min. # of Trials
Acquisition of baseline relations	A1B1, A2B2, A3B3,B1C1,B2C2, B3C3	100	36
All trial types presented randomly	C1D1,C2D2, C3D3, D1E1,D2E2, D3E3		
Maintenance: Thinning of programmed consequences			
	A1B1, A2B2,A3B3,B1C1, B2C2, B3C3	75	36
	C1D1, C2D2, C3D3,D1E1,D2E2, D3E3		
	A1B1, A2B2,A3B3,B1C1, B2C2, B3C3	50	36
	C1D1, C2D2,C3D3, D1E1,D2E2, D3E3		
	A1B1, A2B2, A3B3,B1C1,B2C2, B3C3	25	36
	C1D1, C2D2, C3D3,D1E1,D2E2, D3E3		
	A1B1, A2B2, A3B3,B1C1, B2C2,B3C3	0	36
	C1D1, C2D2, C3D3,D1E1,D2E2, D3E3		
Test for derived relations			
All trial types presented randomly	Baseline trials		
	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3	0	36
	C1D1, C2D2, C3D3, D1E1, D2E2, D3E3		
	Symmetry trials		
	B1A1, B2A2, B3A3, C1B1, C2B2, C3B3	0	36
	D1C1, D2C2, D3C3, E1D1, E2D2, E3D3		
	1 Node trials		
	A1C1, A2C2, A3C3, C1A1, C2A2, C3A3,		
	B1D1, B2D2, B3D3, D1B1, D2B2, D3B3,	0	54
	C1E1, C2E2, C3E3, E1C1, E2C2, E3C3,		
	2 Node trials		
	A1D1, A2D2, A3D3, D1A1, D2A2, D3A3,	0	36
	B1E1, B2E2, B3E3, E1B1, E2B2, E3B3		
	3 Node trials		
	A1E1, A2E2, A3E3, E1A1, E2A2, E3A3	0	18

Table 2. *Overview of phases in the identity or arbitrary simultaneous and delayed matching-to-sample training. The first line of trials is for the groups with identity matching and second line of trials is for the groups with arbitrary matching*

Experimental Phases	Trial Types	% of Programmed Consequences	Min. # of Trials
Acquisition of baseline trials (Randomized)			
	C1/**C1**-C2-C3, C2/C1-**C2**-C3, and C3/C1-C2-**C3** C1/**X1**-X2-X3, C1/X1-**X2**-X3, and C1/X1-X2-**X3**	100	36
Maintenance: Thinning of programmed consequences			
	C1/**C1**-C2-C3, C2/C1-**C2**-C3, and C3/C1-C2-**C3** C1/**X1**-X2-X3, C1/X1-**X2**-X3, and C1/X1-X2-**X3**	75	18
	C1/**C1**-C2-C3, C2/C1-**C2**-C3, and C3/C1-C2-**C3** C1/**X1**-X2-X3, C1/X1-**X2**-X3, and C1/X1-X2-**X3**	25	18
	C1/**C1**-C2-C3, C2/C1-**C2**-C3, and C3/C1-C2-**C3** C1/**X1**-X2-X3, C1/X1-**X2**-X3, and C1/X1-X2-**X3**	0	72

Table 3. Accurate selection of class indicative comparisons in the two test blocks.

Condition	Participant	% correct in test block 1	% correct in test block 2
ABS	4324	84	81
	4346	73	76
	4326	72	69
	4308	68	64
	4310	56	59
	4350	36	53
	4347	49	53
	4302	44	46
	4355	52	44
	4309	39	42
PIC	4344	**99**	**100**
	4335	**99**	**100**
	4303	**99**	**99**
	4323	**97**	**98**
	4319	**98**	**99**
	4312	**96**	**99**
	4305	**97**	**98**
	4359	88	**90**
	4317	77	71
	4339	33	27
Id_STMS	4331	88	**96**
	4358	80	88
	4333	68	68
	4343	66	59
	4337	63	53
	4307	47	57
	4345	50	44
	4300	50	36
	4342	41	32
	4327	37	24
Id_6s-DTMS	4336	**99**	**99**
	4332	**100**	**98**
	4356	**98**	**98**
	4348	**94**	**99**
	4306	80	79
	4320	73	79
	4325	52	71
	4330	58	43
	4328	51	40
	4340	49	41
Arb_STMS	4357	**92**	**99**
	4352	86	**97**
	4353	86	84
	4316	63	58
	4304	52	50
	4329	43	39
	4314	40	36
	4315	44	43
	4313	34	43
	4321	33	23
Arb_6s-DTMS	4322	**100**	**99**
	4311	**99**	**100**
	4349	**100**	**99**
	4338	**98**	**99**
	4341	**97**	**100**
	4351	70	66
	4318	64	76
	4334	56	70
	4354	53	50
	4301	52	51

Table 4. Number of correct responses in Classes 1–3 and participant-defined trial types.

Participant	Condition	Class 1	Class 2	Class 3	Participant-defined Trial Types	Trial types
4324	ABS	44	45	60	1	B2D1
4326	ABS	49	42	37	3	B2D3, D2A3, C3D2
4346	ABS	45	36	51	3	C1E2, E1B3, E2B1
4347	ABS	27	40	29	3	B1E3, E1C3, D2A3
4310	ABS	35	31	37	6	D1A3, B2D3, C2E3, D2B3, E2A3, E3C2
4350	ABS	27	30	24	6	A1B2, B1C3, B1D3, B2A3, B2E3, D3C2
4302	ABS	18	38	27	9	B1C3, B1E3, D1A2, E1B2, E1C2, A2D1, C2D1, C2E1, C3B2
4308	ABS	51	33	35	11	A1E2, B1E2, C1E2, A2E3, C2E3, E2C1, B3D2, C3D2, D3A2, E3A2, E3C2
4309	ABS	21	22	30	14	A1E3, B1C2, C1E3, A2E3, B2A3, B2E3, C2A3, C2E3, D2A3, E2A3, E2D3, A3B2, D3C2, E3D2
4355	ABS	32	33	25	14	A1E2, B1E2, C1E2, E1A3, C2A3, D2E3, E2B1, E2C1,A3D1, A3E2, C3A1, C3E2, D3B2, E3B2
4359	PIC	53	48	59	1	E2B1
4317	PIC	49	48	36	2	E1A3, A3E1
4339	PIC	17	17	20	5	E1C2, A2D3, C2A1, D2A3, A3C2
4333	Id-SMTS	36	38	48	1	C1E2
4358	Id-SMTS	45	58	48	2	E1A3, E3D1
4300	Id-SMTS	26	27	24	2	C2E1, D3A2
4343	Id-SMTS	28	45	39	3	A1E3, D1B2, E1B2
4307	Id-SMTS	33	30	30	6	A1D2, B2A3, C2D3, E2B3, C3A2, D3C2.
4345	Id-SMTS	37	20	28	7	C1B2, B2C1, C2D3, D2B1, D3B2, E3B1, E3C2.
4307	Id-SMTS	33	30	30	8	A1D2, B2A3 C2D3, D2B3, E2B3, C3A2, D3C2, E3C2
4337	Id-SMTS	32	39	34	8	B1D2, C1E3, C2E3, E2B1, B3E1, C3A2, D3A2, E3C2.
4342	Id-SMTS	23	20	26	8	C1A3, D1B3, E1C3, A2C3, B2D1, A3E2, C3A2, D3C2
4327	Id-SMTS	23	16	16	8	A1E3, B1E3, A2B1, B2A1, D2A1, D2E3, B3E1, D3A1
4306	Id-DMTS	43	49	51	2	A1E2, B1E2
4330	Id-DMTS	30	36	25	3	A1C3, A3E1, D3C2
4320	Id-DMTS	42	36	59	5	A1D2, B1D2, C1D2, D2A1, D2B1
4328	Id-DMTS	25	28	29	14	A1C2, B1E3, D1B2, E1B2, E1C2, E1D3, A2D3, C2E1, C2A3, C2D3, D2A3, A3C2, D3B2, E3C2
4340	Id-DMTS	25	25	31	15	C1E2, C1A3, D1B2, D1C2, D1A3, E1C2, A2E3, C2A3, C2E3, D2A3, E2D1, E2A3, A3D1, A3C2, E3C2
4325	Id-DMTS	36	33	42	N/A	N/A
4353	Arb-SMTS	42	60	51	1	D1B3
4316	Arb-SMTS	44	30	35	1	A2D3
4304	Arb-SMTS	34	36	22	4	A3E2, B3D2, E3A2, E3B2
4315	Arb-SMTS	23	29	28	5	A1D3, C1B3, B2D1, B2E1, C3B1.
4329	Arb-SMTS	29	33	12	7	A3E2, B3A1, B3D2, B3E2, D3C1, D3A2, E3D2
4314	Arb-SMTS	17	30	23	8	B1C2, B1E3, C1E3, E1C2, C2D3, A3C2, C3A1, D3A1
4321	Arb-SMTS	15	18	18	14	A1E3, C1E3, D1E2, D1C3, B2C3, B2E3, D2A3, D2B3, E2D1, E2C3, A3D2, B3D2, D3B2, E3D1
4313	Arb-SMTS	22	26	22	N/A	N/A
4318	Arb-DMTS	46	46	34	2	D3B1, E3C1
4351	Arb-DMTS	34	55	33	6	A1D3, C1D3, D2A3, A3D1, C3D1, C3E1
4334	Arb-DMTS	35	42	36	8	A1D3, A1E3, A3C2, A3E2, B3A1, C3A1, D3A1, E3A1
4354	Arb-DMTS	31	28	34	9	A1D3, B1E3, C1E3, B2E3, C2A1, C2E3, C3B1, D3C1, E3B1
4301	Arb-DMTS	32	31	30	26	B1A3, C1A2, C1B2, D1A2, E1A2, E1B2, E1C2, E1D2, B2A3, C2A3, C2B3, D2A3, D23, E2A3, E2B3 E2C3, E2D3, B3A1, C3B1, D3A1, D3B1, D3C1, E3A1, E3B1, E3C1, E3D1

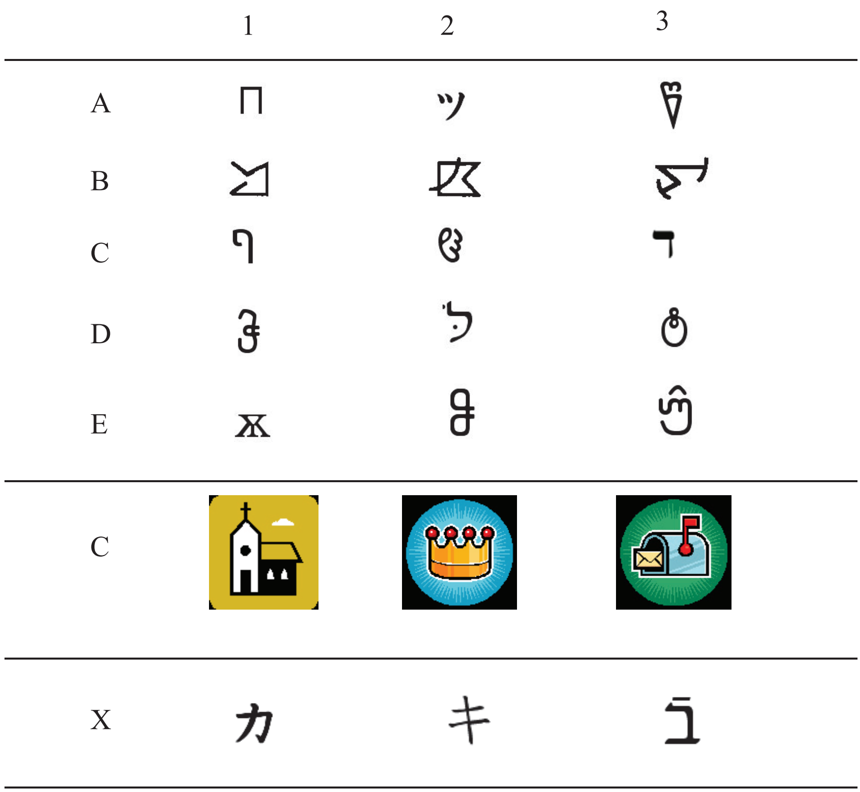

Figure. 1. The stimuli used as members of the equivalence classes were the abstract and familiar picture-stimuli as shown in the two top sections. The bottom section shows the stimuli used during the arbitrary matching training.

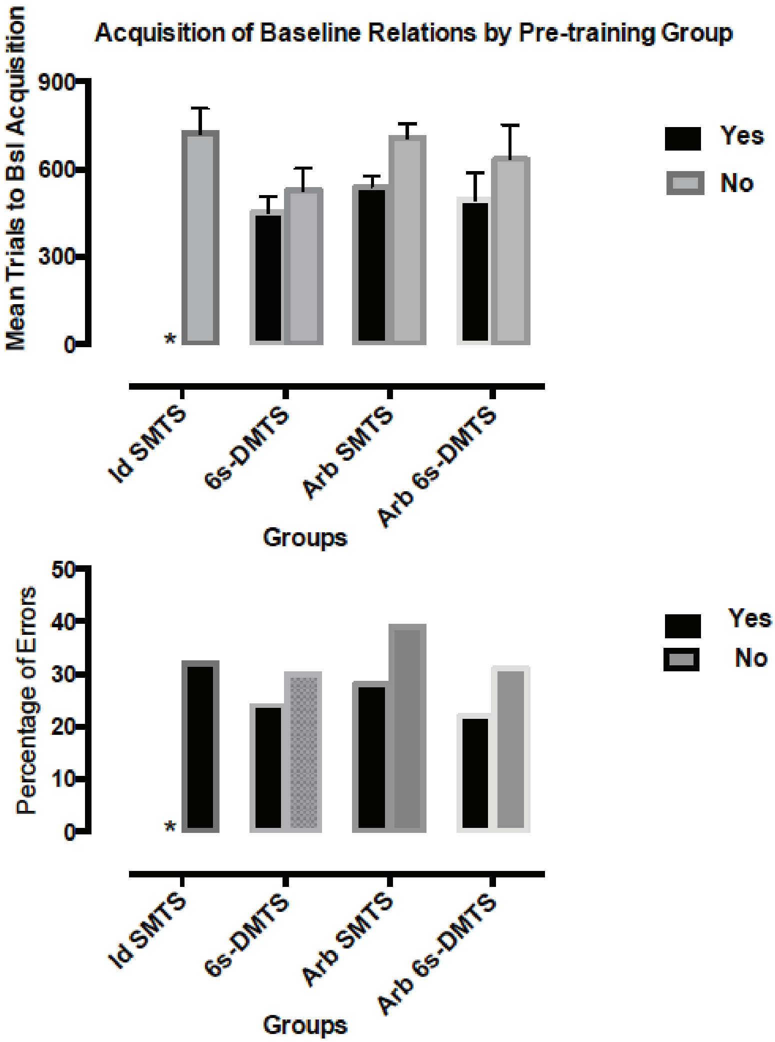

Figure 2. The upper panel shows the mean number of trials to criterion for baselline for each group. The lower panel shows the percentage of errors for each group. Abs=all stimuli were abstract shapes, Id SMTS=C stimuli were pre-trained with simultaneous identity matching, Id 6s-DMTS=C stimuli were pre-trained with 6 s delayed identiity matching to sample, Arb SMTS=C stimuli were pre-trained with arbitrary simultaneous matching, C stimuli were pre-trained with 6 s delayed arbitrary matching to sample and Yes indicates class formation and No indicates no class formation. *=no participants responded in accordance with stimulus equivalence.

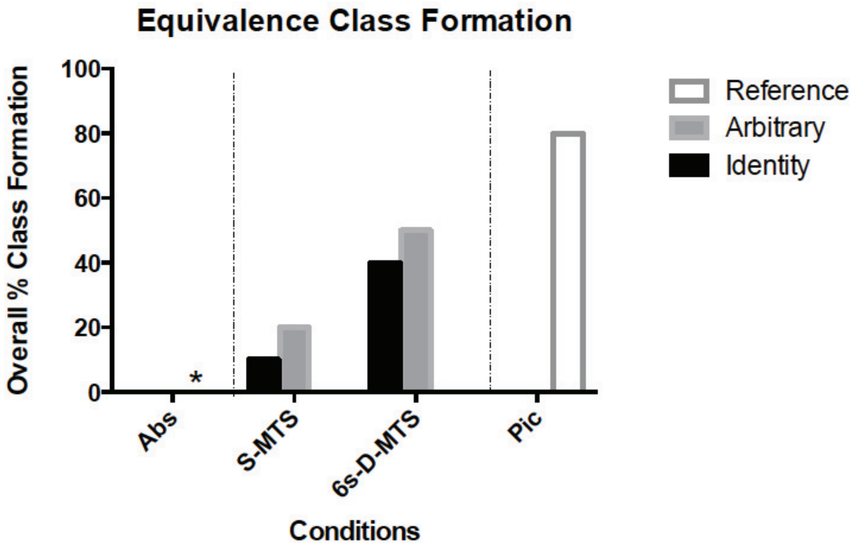

Figure 3. The figure shows percentage of participants responding in accordance with stimulus equivalence (immediate and delayed). Abs=all stimuli were abstract shapes, S-MTS=C stimuli were pre-trained with simultaneous identity or arbitrary matching, 6s-DMTS=C stimuli were pre-trained with 6 s delayed identity or arbitrary matching , Pic=C stimuli were pictures. *=no participants responded in accordance with stimulus equivalence.

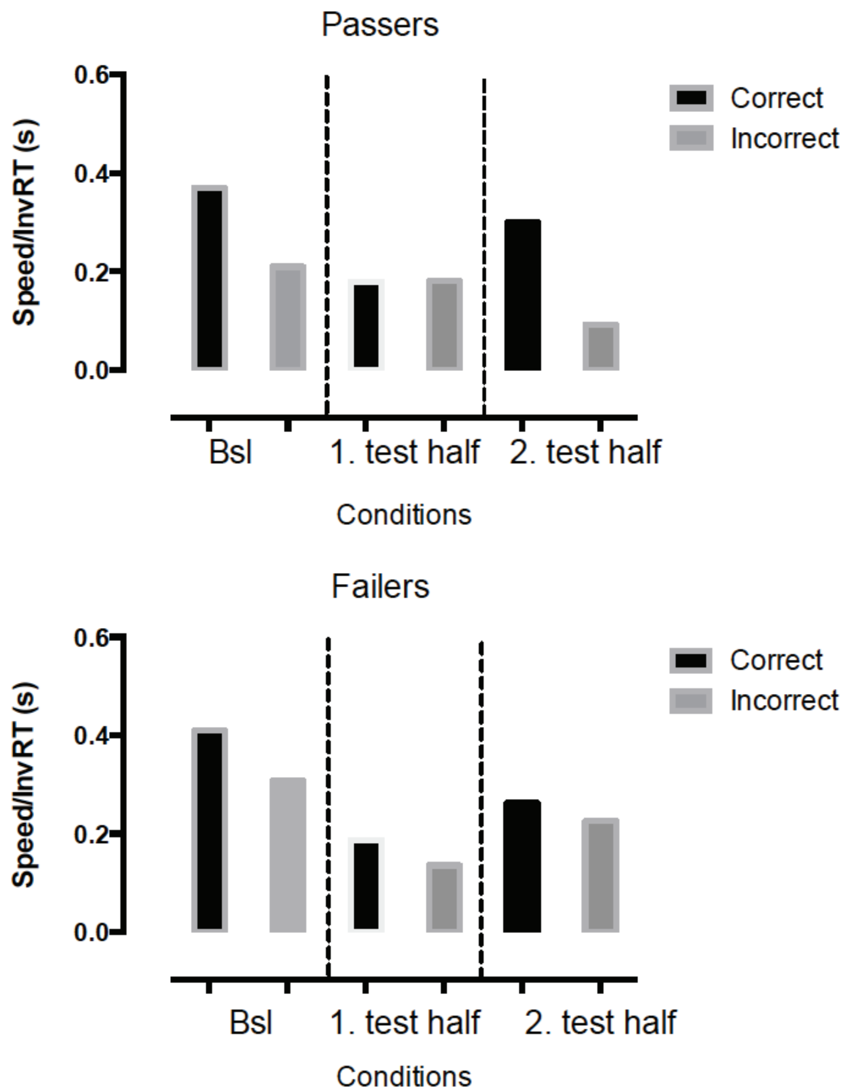

Figure 4. The figure shows average speed for participants in all groups. The upper half of the figure shows speed for the participants responding in accordance with stimulus equivalence (passers) and the lower half shows speed for the participants not responding in accordance with stimulus equivalence. The scores are divided if the choices were correct vc. incorrect during baseline (Bsl), first and second test half.

Errata

Page i, line 4

The meaningfulness of the stimuli used has been found to be a very important variable that influences the probability of forming equivalence classes.

Is changed to:

The meaningfulness of the stimuli used has been found to be one of such important variables.

Page i, line 26

In addition to their traditional connotative and denotative, these studies…

Is changed to:

In addition to their traditional connotative and denotative properties, these studies…

Page i, line 34

…as well as its behavioral functions interact with the meaningful stimulus to account for the class enhancement.

Is changed to:

…as well as its behavioral functions interact with the meaningful stimulus to account for their class enhancement.

Page 5, line 3

Researchers have investigated these and other complex phenomena under broad areas as categorization,

Is changed to:

Researchers have investigated these and other complex phenomena under broad areas such as categorization,

Page 7, line 1

First of all, some concepts that will make our understanding of the stimulus equivalence when it is introduced later in this introduction will be discussed now.

Is changed to:

First of all, let us discuss some concepts that will help us understand stimulus equivalence when it is introduced later in this introduction.

Page 9, line 12

MTS could be either *identity matching*...

Is changed to:

MTS could either be *identity matching*...

Page 11, line 5

Functional stimulus classes on the other hand refer to classes of stimuli that do share common physical characteristics among members but control the same response.

Is changed to:

Functional stimulus classes on the other hand, refer to classes of stimuli that do not share common physical characteristics among members but control the same response.

Page 11, line 22

… members with another without altering the probability of a particular response occurring.

Is changed to:

… members with one another without altering the probability of a particular response occurring.

Page 12, line 17

Using the typical matching-to-sample procedure, a child who speaks only English can be taught to relate the English "Pig"…

Is changed to:

Using the typical matching-to-sample procedure, a child who speaks only English can be taught to relate the English word "Pig"…

Page 13, line 16

… pigRporc, and porc**R**gris, the emergence of gris**R**pig without…

Is changed to:

…pig**R**porc, and porc**R**gris, the emergence of gris**R**pig without…

Page 17, line 5

Horne and Lowe (1996)suggest that naming,

Is changed to:

Horne and Lowe (1996) suggest that naming,

Page 18, line 14

constitute an equivalence classes if…

Is changed to:

constitute an equivalence class if …

Page 18, line 22

first before experience modifies or break them down.

Is changed to:

first before experience modifies or breaks them down.

Page 20, line 17

no such facilitation effect on class formation.

Is changed to:

no such facilitating effect on class formation.

Page 21, line 15

In one such study that had found meaningful pictures…

Is changed to:

In one such study that has found meaningful pictures…

Page 28, line 14

or the other that are not been mentioned here so far.

Is changed to:

or the other that have not been mentioned here so far

Page 29, line 9

(a) multi-nodal equivalence classes are less likely to form when all class members are abstract stimuli (meaningless)

Is changed to:

(a) multi-nodal equivalence classes are less likely to be formed when all class members are abstract stimuli (meaningless)

Page 31, line 2

The principle of full disclosure, however, may not be fully adhered to in this project because I do not intend to tell participants more about the experiment before they participate for fear of confounding the experiment.

Is changed to:

The principle of full disclosure, however, was not be fully adhered to in this project because I did not intend to tell participants more about the experiment before they participate for fear of confounding the experiment.

Page 32, line 4

Trying to find what the best things to do to address these ethical concerns, questions have been asked about when is the right time to pay?

Is changed to:

Trying to find what the best things to do to address these ethical concerns, questions have been asked about when is the right time to pay?

Page 32, line 11

It should be said also that,

Is changed to:

It should also be said that,

Page 35 line 12

Study 1 - Nartey, R.K., Arntzen, E., & Fields, L. (accepted). Enhancement of equivalence class formation by pre-training discriminative functions

Is changed to:

Study 1 - Nartey, R. K., Arntzen, E., & Fields, L. (2014). Enhancement of equivalence class formation by pre-training discriminative functions. *Learning & Behavior*. doi: 10.3758/s13420-014-0158-6

Page 35, line 18

Study 2 - Nartey, R.K., Arntzen, E., & Fields, L. (2014). Two functions of meaningful stimuli disclosed by equivalence class formation: conditional discriminative functions. *The Psychological Record*. doi: 10.1007/s40732-014-0072-5

Is changed to:

Study 2 - Nartey, R.K., Arntzen, E., & Fields, L. (2014). Two discriminative functions of meaningful stimuli that enhance equivalence class formation. *The Psychological Record*. doi: 10.1007/s40732-014-0072-5

Page 36, line 20

Study 4 - Arntzen, E., Nartey, R.K., & Fields, L. (2014). The identity functions of meaningful stimuli and enhanced equivalence class formation. *The Psychological Record*. doi: 10.1007/s40732-014-0066-3

Is changed to:

Study 4 - Arntzen, E., Nartey, R.K., & Fields, L. (2014). Identity and delay functions of meaningful Stimuli: enhanced equivalence class formation. *The Psychological Record*. doi: 10.1007/s40732-014-0066-3

Page 37, line 11

Study 5 - Arntzen, E., Nartey, R.K., & Fields, L. (submitted). Enhancing equivalence class formation by the delayed and relational properties of meaningful stimuli.

Is changed to:

Study 5 - Arntzen, E., Nartey, R.K., & Fields, L. (submitted). Enhancing responding in accordance with stimulus equivalence by the delayed and relational properties of meaningful stimuli.

Page 44, line 11

… classes were formed by 0% of participants while 70% of participants in the PIC group formed classes.

Is changed to:

… classes were formed by 0% of participants while 80% of participants in the PIC group formed classes.

Page 45, line 12

… and thus, it likely forms categories with their associated stimuli, akin to generalized equivalence classes

Is changed to:

… and thus, they likely form categories with their associated stimuli, akin to generalized equivalence classes

Page 50, line 3

The discussion will continue here because results from this study have some implications on the naming account.

Is changed to:

The discussion will continue here because results from some of the studies presented here have some implications for the naming account.

Page 50, line 12

… the participants may name the various stimuli in their own ways…

Is changed to:

… the participants may have named the various stimuli in their own ways…

Page 51, line 4

… Sidman (1994) that naming is could be facilitative but not a necessary prerequisite for the formation of equivalence classes.

Is changed to:

… Sidman (1994) that naming could be facilitative but not a necessary prerequisite for the formation of equivalence classes.

Page 62

Nartey, R. K., Arntzen, E., & Fields, L. (accepted). Enhancement of equivalence class formation by pre-training discriminative functions. *Learning & Behavior*.

Is changed to:

Nartey, R. K., Arntzen, E., & Fields, L. (2014). Enhancement of equivalence class formation by pre-training discriminative functions. *Learning & Behavior*. doi: 10.3758/s13420-014-0158-6

Page 67

Nartey, R.K., Arntzen, E., & Fields, L. (accepted). Two discriminative functions that enhance equivalence class formation: the class enhancing properties of meaningful stimuli. *Learning & Behavior*.

Is changed to:

Nartey, R. K., Arntzen, E., & Fields, L. (2014). Enhancement of equivalence class formation by pre-training discriminative functions. *Learning & Behavior*. doi: 10.3758/s13420-014-0158-6

Page 162

Enhancing Equivalence Class Formation by the Delayed and Relational Properties of Meaningful Stimuli

Is changed to:

Enhancing Responding in Accordance with Stimulus Equivalence by the Delayed and Relational Properties of Meaningful Stimuli

Page 162

Arntzen, E., Nartey, R.K., & Fields, L. (submitted). Class enhancement as a function of meaningful stimuli and pre-training with delayed matching-to-sample.

Is changed to:

Arntzen, E., Nartey, R. K., & Fields, L. (submitted). Enhancing responding in accordance with stimulus equivalence by the delayed and relational properties of meaningful stimuli.

Page 164, line 13

Classes were formed by 70% and 0% of participants in the PIC and ABS groups, respectively

Is changed to:

Classes were formed by 70% and 0% of participants in the PIC and ABS groups, respectively

Page 164, line 14

Yields were an inverse function of delay…

Is changed to:

Yields were a direct function of delay…

Page 175, line 20

… equivalence class formation was an inverse function of the delay…

Is changed to:

… equivalence class formation was a direct function of the delay…