Mimicking Meaningfulness

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Stimulus Equivalence and Meaning

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Abstract

The current paper reflects on some of the basic issues in the concept of stimulus equivalence as proposed by Murray Sidman. The paired-associate paradigm was the predominant method being employed to demonstrate how organisms come to treat dissimilar events that had not been related before as if they were the same. Several papers by Murray Sidman after the demise of the pair-associates methodology brought a paradigm shift in stimulus equivalence research from the paired-associates realm to the study of the properties of reflexivity, symmetry, and transitivity through conditional discrimination training. Stimulus equivalence research has since been conducted with different organism (nonhumans and humans), adults, children, autistic children, amongst others, and with stimuli of different modalities (familiar pictures, abstract stimuli, tactile, etc.). A very important focus of this paper is to review papers on the use of meaningful or familiar stimuli in the equivalence research so far and finally suggest directions for future researchers on the use of meaningful stimuli in equivalence research.

Keywords: Stimulus equivalence, Conditional discrimination, Meaning, Naming.

Stimulus Equivalence and Meaning

How organisms come to treat dissimilar events, particularly events that have never been related directly as if they are the same have been an interesting question for many philosophers and psychologists. Early researchers employed paired-associates methods in attempts to determine how humans might come to demonstrate this phenomenon they labeled *stimulus equivalence* (Green & Saunders, 1998). Research on stimulus equivalence, however, was minimal after the demise of the paired-associates methodology, and was only revived in the 1970s through the works of Murray Sidman and his colleagues and had since been a very important research area in the field of experimental behavior analysis (Green & Saunders, 1998). This paper has two main objectives. First, it discusses the subject of *meaning,* and then revisits some of the works on the experimental analysis of stimulus equivalence consistent with the Sidman analysis introduced in 1982 (e.g., Sidman et al., 1982; Sidman & Tailby, 1982) and subsequently refined (Carrigan & Sidman, 1992; Sidman, 1992, 1993, 2000, 2009)

The meaning of *meaning*.

Many authors from different disciplines view the subject *meaning* as a troublesome one to discuss (e.g., McCabe & Mandell, 1997). In that paper, the authors rightly put that as "the very act of defining *meaning* itself presents a challenge". They however said meaning could be discussed from a global perspective, as in making sense of the events around us, or from a more specific perspective, as in making sense of a word, utterance, action, etc.

Szalay and Deese (1978) discussing the meaning of words talked of *lexical meaning*, *referential meaning*, and *psychological meaning*. Lexical meaning is the conventional and arbitrary relation between a word and its referent while referential meaning refers to the concept-referent relation. A person's subjective perception and affective reactions to segments of language refers to psychological meaning. To them, both lexical and referential meaning emphasize the arbitrary nature of the nature between a word and its referent but that could also be dangerous for valid conclusions. Psychological meaning, according to them, is a reaction subject to rules and controlled by characteristic dispositions. The notion of mediation was alluded to as being responsible for the explanation of psychological meaning since it made it possible to deal with and explain cognitive processes by conceiving of them as mediating chains with one or more covert links.

Giving a broad multi-disciplinary historical account of the use of meaning, Smith (1997) lists a number of concepts that have been related to the notion of meaning and have even been used certain times to explain it. Some of these concepts include sense, connotation, denotation, reference, intention, extension, definition, symbols, signs, tacts, mands, and many others. Four basic approaches to the theory of meaning are reported in his account, namely: the *referential*, *mentalist*, *contextualist*, and *dissolutionist* approaches. The referential approach specifies the meaning of an expression by identifying what it refers to in the environment. The notion of naming is thus employed in this approach. Though this approach seems appealing because of its instinctive nature, there are some difficulties with the approach. First, it cannot account for the meanings of mythical or abstract entities. It also struggles to handle instances where expressions with different meanings prove to have the same referent.

The mental approach, as its name suggests, identify meanings with mental contents in the form of images, concepts and intentions. The individual's mind is where the meanings are carried and they get transmitted or conveyed when one's utterances with certain images in mind, results in the circumstance where the listener also develop similar images and concepts in his mind. This approach, in contrast to the referential approach pays little attention to the social and environmental dimensions of language.

In an attempt to eliminate the problems associated with seeking meaning in individual minds or in the attachment of words to certain specific entities in the world, the contextual approach seeks meaning in the complex relations between the language user and the context. This approach has also got its own criticisms such as its failure of clearly stating the relations and the contexts.

The dissolutionist approach believes that meaning related phenomena are handled at a level that makes it difficult for the use of the concept of meaning. To them, since meanings are diffused across complex organism-environment relations, they should no longer be grouped under the term “meaning”. One of the criticisms of this approach is that, simply dissolving the problem does not necessarily solve it.

A definition of meaning from the behaviorist view will discard the use of all mental entities. Such a definition could instead be seen in the form of associations brought into material form as conditioned relations where a word can come to stand for an object through a process of stimulus substitution. This accounts for instances where people treat dissimilar objects that have never been directly related before as if they are the same. When a group of demonstrators against a government or a state burns the flag of the nation, it is because both country and the flag mean the same thing for them. Also, after a matching-to-sample task in an equivalence test, if results show that a participant responded in accord with equivalence, it is because the members of the experimentally defined classes have come to mean the same thing for the participant.

If meaning is a feature of verbal behavior, then it should be able to measure some of its properties, for instance how different meanings affect the latencies of responses to them

(Catania, 2007). What determines what a word means? Galton (as cited in Catania, 2007), finds word associations as the basis for measuring meaning. Thus, if one produces longer and more varied lists of words in response to one word than another, then the first word is adjudged more meaningful than the other. Word association as a measure for meaning also suggests that words closely related in meaning would occasion overlapping lists of associates.

Stimulus equivalence defined

Murray Sidman and his colleagues, after the demise of paired-associates methodology, spearheaded the stimulus equivalence researches with the introduction of some influential articles especially in 1982. By then, they had gotten rid of some of the terms that existed during the paired-associates era. In addition, Sidman and his colleagues introduced reflexivity, symmetry, and transitivity as properties of responding that describe the emergent relations they encountered in their experiments after training a few. These three properties were borrowed from the mathematical set theory and are the defining relations of stimulus equivalence (Sidman, Kirk, & Willson-Morris, 1985; Sidman et al., 1982; Sidman & Tailby, 1982). They however only describe relations among stimuli because the existence of these relations can only be deducted from the responding of an organism (Sidman et al., 1982; Sidman & Tailby, 1982).

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.* Condition discriminations such as “if A, then B”, are often assumed to demonstrate not just conditional relations between stimuli, but equivalence relations also and requires additional tests to determine whether a subject’s performance involves something more than conditional relations between sample and comparison stimuli. Using a matching-to-sample procedure, a subject can be taught to match stimulus **A** to **B**, and then match stimulus **B** to **C.** If the relation, **R** between the stimuli trained fulfils the requirement for conditionality, then one can say that A**R**B and B**R**C have then been established. Appropriate tests derived from the three defining properties of reflexivity, symmetry, and transitivity will proof if the conditional relations are also equivalent relations.

For the conditional relation, **R**, to be said to be reflexive, one must show that each stimulus bears the relation to itself; ARA (if A, then A), BRB (if B, then B) and CRC (if C, then C) must hold true. Sidman (1992) suggests that a subject who behaves this way without explicit reinforcement is showing *generalized identity matching*. It is therefore correct to say that, identity matching-to-sample (MTS) test with the stimuli under study is the test for reflexivity which requires the subject to match stimulus a to itself, b to itself, and c to itself. For the relations, R to be symmetric, ARB and BRA, as well as BRC and CRB must hold true. Thus, the conditional relations must be bidirectional. If a sample **A** has been related to comparison **B**, and **B** related to **C** in training, then relating B to A, and C to B should emerge without any further training or programmed reinforcements. This is to say that, the sample and comparison are interchangeable in function, such that samples function effectively as comparisons with former comparisons as samples. Sidman et al. (1982) rightly termed the proof of symmetry, “functional sample-comparison reversibility”. If after the two conditional relations ARB and BRC, are explicitly taught, the relation **A** to **C** emerges without further instructions, then the relations are said to be transitive. Transitive responding, thus, involves the novel combination of stimuli related through shared class membership (If ARB and BRC, then ARC) (Sidman & Tailby, 1982). When relational responding reflects that the properties reflexivity, symmetry, and transitivity have emerged, it can then be said that a stimulus equivalence class has been established.

On a more applied note, assuming one wants to establish the equivalence class pig for a an English speaking child who prior to that does not speak Norwegian or French, first pig can be conditionally related to the French word porc, and the French word porc related to the Norwegian word for pig, gris. After the conditional relations are established, the child, without further reinforcements or instructions, should demonstrate reflexivity, thus, relate each stimulus to itself (pig R pig; porc R English word porc; and gris to gris), then show bi-directionality in each of the relations (symmetry) by relating the French word porc to the English word pig, and then the Norwegian word gris to the French word porc. Transitivity requires that, the child relates pig to the Norwegian word gris without further training. When all of these relations are demonstrated, one can safely say that the English word pig, the French word porc, and the Norwegian word gris form an equivalence class for the child (Green & Saunders, 1998; R. R. Saunders & Green, 1992; Sidman & Tailby, 1982). The equivalence class could be expanded by teaching the child to relate the Norwegian word “gris” to its corresponding word in French, for instance and the number of emergent relations will increase (e.g., Sidman et al., 1985; Sidman & Tailby, 1982).

Stimulus equivalence can be said to be synonymous with stimulus substitution (Green & Saunders, 1998). When a stimulus which is controlling some behavior may be replaced by another stimulus and the probability for the occurrence of the response is not altered, it is possible to assume that the stimuli “mean” the same for the organism. The most fascinating phenomenon about stimulus equivalence research is when the stimuli used in the classes are not linked by their physical characteristics but when they are arbitrarily linked like Greek and Hebrew letters for participants to whom the stimuli has no meaning before the experiment.

Stimulus equivalence research has evolved tremendously since the 1982 articles by Murray Sidman and his colleagues. Research has been conducted using different protocols (Imam, 2006) and different training structures (e.g., K. J. Saunders, Saunders, Williams, & Spradlin, 1993). Stimulus equivalence has been demonstrated in verbally competent humans (e.g., Arntzen & Holth, 2000a; Pilgrim & Galizio, 1995; Randell & Remington, 1999; Sidman & Tailby, 1982) but not in nonhumans (Dugdale & Lowe, 2000).

Three different training structures have been used in the conditional discrimination training in equivalence researches. They are one-to-many (OTM), many-to-one (MTO), and linear series (LS). In OTM, a single stimuli serving as a sample is trained to at least two comparisons, hence the name "*sample-as-node*" (K. J. Saunders et al., 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). MTO has been found to be the most effective training structure, i.e., training with MTO structure has produced higher yields on equivalence (Arntzen & Vaidya, 2008)

Equivalence class formation has been shown to be affected by the number of nodes of the equivalence class (Fields & Verhave, 1987). Different modalities of stimuli have also been used. Studies has been done using olfactory stimuli (Annett & Leslie, 1995), tactile (Belanich & Fields, 1999) and visual (e.g., Arntzen, 2004; Arntzen & Lian, in press; Sidman & Tailby, 1982). Visual stimulus materials used in studies and reported in the literature so far could be different abstract stimuli (Sidman & Tailby, 1982), familiar or meaningful pictures (Arntzen, 2004; Arntzen & Lian, in press), and consonant-vowel-consonant syllable CVCs (Fields, Reeve, Rosen, Varelas, & Adams, 1997).

All of these variables have been shown to be influential in one way or another to equivalence class formation but the major focus of this paper will be on the use of meaningful or familiar pictures in stimulus equivalence experiments. The rest of this paper will review some literature on stimulus equivalence research with meaningful stimuli and a few literatures on meaning in Cognitive psychology.

Stimulus equivalence and meaning

Holth and Arntzen (1998) reported in their paper that familiar stimuli could affect equivalence class formation. The experiment compared the probabilities of equivalence formation when all the stimuli were Greek letters, and when A, and C, only B, or only C stimuli were meaningful stimuli and the remaining stimuli were Greek letters in a linear series training structure. The results showed a low probability of equivalence when the stimuli were all Greek letters. The probability of equivalence however varied depending on whether the A, B, and/or C stimuli were familiar pictures. The highest probability of equivalence was reported when the pictures served as B-stimuli, where 10 out of 10 subjects responded in accord with equivalence.

In a similar study, Arntzen (2004) investigated how responding in accord with equivalence relations changes as a function of the position of familiar stimuli, pictures, and with the use of nonsense syllables in an MTO-training structure (AB, CB, DB, and EB) designed to produce three 5-member classes. Fifty university or college students recruited from psychology and behavior analysis classes were randomly assigned to five experimental groups and exposed to different sets of stimuli: (a) Only Greek and Arabic letters, (b) Greek, but A-stimuli replaced by pictures, (c) Same as (b) but the training sequence reversed so that the pictures were introduced at the end (as E-stimuli), (d) Greek stimuli, but with the A-stimuli replaced by nonsense syllables, and (5) same as (b), but with presses on the keyboard rather than touches on the touch screen. Results from the study showed that familiar stimuli, when introduced first (as A-stimuli) is very effective in establishing responding in accord with equivalence. 10 out of 10 in that condition responded in accord with equivalence, whereas introducing the pictures at the end of the training (as E-stimuli) produced a lower yield (5 out of 10). It was lower (4 out of 10) when nonsense syllables were used, 3 out of 10 when all the stimuli were Greek and Arabic letters only. When A-stimuli were familiar pictures but with a requirement of key presses on the keyboard, 4 out of 10 responded in accord with equivalence.

A further study, Arntzen and Lian (in press) investigated in typically developed children (1) if the different types of stimuli sets with and without familiar picture-stimuli as nodes influenced the number of trials to criterion during training of conditional discriminations and (2) the effects of responding in accord with equivalence as a function of different stimuli sets, i.e., abstract vs. familiar. The authors also sought to investigate the differences in number of trials and equivalence class formation when the participants were exposed to a condition with familiar picture-stimuli before a condition with the abstract stimuli only and its reverse. Differences in reaction times from training to test for the abstract vs. familiar picture-stimuli condition, as well as differences between symmetry and equivalence tests were also studied. Sixteen children were trained to form three 3-member classes in an MTO training structure and were randomly assigned to two different experimental conditions. Half of the children were first exposed to the condition with all abstract stimuli and then to a condition in which new abstract stimuli served as samples and 3 picture stimuli served as comparisons and the nodes. The next half of the participants were first given the condition with samples as abstract stimuli and 3 picture stimuli serving as comparisons and nodes before being exposed to a condition with all abstract stimuli. Results from the experiments showed that, irrespective of which stimuli sets were presented to the participant first, the condition with familiar picture stimuli as nodes was more effective in producing responding in accord with equivalence than stimuli sets with abstract stimuli only. More participants responded in accord with equivalence when they were trained with familiar pictures first. Specifically, for all of the participants, regardless of order of stimulus sets showed that, 8 out of 16 responded in accord with equivalence in the abstract-stimuli-only condition, whilst 13 out of 16 responded in accord with equivalence in the picture as node condition. For participants who started with the abstract-stimuli-only condition, 2 responded in accord with equivalence in the first condition and all participants responded in accord with equivalence in the condition with familiar picture stimuli as node. For those who started with the familiar picture-stimuli as nodes condition, 6 participants responded in accord with equivalence when familiar picture-stimuli were nodes, and six participants responded in accord with equivalence when all the stimuli used were abstract.

The reaction time to the comparison stimuli increased from baseline trials to equivalence tests, than to symmetry test trials, and most importantly increased with abstract stimuli than with pictures as nodes. The results also showed that the number of trials to establish baseline relations were much lower under the picture-as-nodes condition than under the abstract-stimuli-only condition regardless of the order of the presentation of stimuli sets in the participants. The mean number of trials to criterion for the participants starting with picture-as-nodes was 171 for the first condition and 202 for the second condition. With those that started with the abstract-stimuli-only condition, the mean number of trials for the first condition was 297, and that for the second condition was 171. A very important inference from that study is that the experimental history with familiar picture-stimuli had a significant effect on the subsequent training of classes with abstract stimuli.

Meaningfulness of stimulus has also been defined in some studies as the probability that the stimuli can be easily named. Though one cannot authoritatively defend the naming hypothesis (Horne & Lowe, 1996), there are compelling works in that paradigm. It is demonstrated that stimulus classes involving readily nameable stimuli can be established more easily than those involving non-nameable stimuli (Bentall, Dickins, & Fox, 1993; Dickins, Bentall, & Smith, 1993; Mandell & Sheen, 1994). The major prediction is that a meaningful stimulus will elicit a verbal response (a name) and that will come to be associated with all other stimuli in that class. Therefore, if equivalence relations require mediated verbal behavior as believed by proponents of the naming hypothesis, then relations suggesting equivalence should easily emerge among stimuli which are readily nameable than those which are not.

In their attempt to distinguish between associative network and verbal mediation accounts of equivalence, Bentall et al. (1993) conducted three different experiments and the findings reported in their paper. In experiment 1, 24 university students were assigned to three different conditions. The conditions differed in the stimuli used in the training. One group of subjects had readily nameable pictograms that fell into clear semantic categories ("preassociated" pictograms), the second group had equally nameable pictograms but did not fall into clear categories ("nonassociated" pictograms), whiles the last group had "nonassociated abstract" stimuli designed to be difficult to name. The results indicates that reaction times during testing as well as error rates were higher with nonassociated pictograms than with associated pictograms, and even much higher with abstract stimuli. Experiment 2 was a systematic replication of Experiment 1, with the experimental conditioned reduced to just two; the group trained with preassociated pictograms and those with abstract stimuli. In that experiment too, they controlled for the number of trials by introducing equal numbers of trained associations, symmetry, transitivity, and transitivity-with-symmetry trials in the test phase. The results in the experiment were consistent with that found in the first experiment. The subjects in Experiment 3 were pretrained to either give individual names or class names to abstract stimuli. Subjects trained to use individual names for stimuli, produced a higher number of errors and had higher response latencies consistent with the associative network account of equivalence. Those taught to assign class names to the abstract stimuli, however, showed low error rates and equal response latencies across the different tests. The general conclusions of the study suggests that, dependent on the stimulus conditions and the strategies employed by subjects, equivalence classes can be said to be either supported by an associative network or verbal mediation.

Mandell (1997), in Experiment 1 of her study, did a systematic replication of the study described above in which she compared the formation of equivalence classes after training with meaningful stimuli to nonmeaningful stimuli but employed a within-subject design rather than between-group used in the original study. This was to make way for greater control over individual and historic differences among subjects. Subjects were expected to acquire eight 3-member stimulus classes after being taught 16 conditional discriminations. Four of the stimulus classes had the sample stimuli as one of the following meaningful pictograms: a frog, a bottle, a plane and a hand whiles the other four stimulus classes had their sample stimuli as well as all the comparison stimuli for all of the classes as abstract (nonmeaningful stimuli). As predicted, results from the study showed that equivalent class formation is facilitated with the use of nameable (meaningful) stimuli than with abstract stimuli, and that, fewer errors would occur with the use of concrete stimuli than with abstract stimuli. Again, reaction times to choice were shown to be shorter with the use of meaningful stimuli than with abstract stimuli. The data from the study, thus, supports the notion that the formation of equivalence classes is mediated by verbal behavior.

Mandell and Sheen (1994) studied the role of naming in stimulus equivalence by varying the pronounceability of the sample stimulus pseudowords and also concluded that equivalence class formation is mediated by verbal behavior. Two experiments were conducted in the study. In experiment 1, there were three experimental conditions with the sample stimuli being the difference among the conditions. In the first, sample stimuli consisted of phonologically correct pseudowords whiles the sample in the second consisted of phonologically incorrect words and in the last condition, the sample stimuli were punctuation marks. Results from the experiment showed that equivalence class formation was easily achieved with pronounceable stimuli than the other stimuli, and that there were more errors made by subjects that were exposed to non-phonological words, and the punctuation mark than was made with the phonological stimuli group. Experiment 2 of the study maintained common sample stimuli for both experimental conditions but pretrianed some of the subjects with the stimuli in order to promote the use of a naming response. The stimuli used were non-phonological. One of the groups was trained to read aloud (pronounce) the non-phonological pseudowords, and the other group trained to transcribe them. This was only done to control for the number of trials so that both set of subjects will have an equal exposure to the stimuli. However, those who were reading aloud during the pretraining were expected to be in an enhanced position of “naming” the non-phonological pseudowords, while exposure to the stimuli through transcription was not expected to alter the likelihood of naming during the actual equivalence testing. Results from this experiment support the naming theory in that, when the subjects were encouraged to attribute names or labels to the non-phonological pseudowords through the reading aloud training, the subjects' performances on the formation of stimulus equivalence classes were enhanced.

In another experiment, Randell and Remington (1999) investigated the role of verbal behavior in equivalence class formation. Three experimental conditions were used; one in which the names of the stimuli forming classes rhymed and two control conditions made up of different combinations of the same stimuli whose names did not rhyme. Results from the study revealed that the acquisition of baseline trials were quickest for participants in the rhyme condition compared to the control conditions. Responding in accord with emergent relations was best with the rhyme condition as well. Response latencies were also lower with participants under the rhyme condition. This finding puts in a strong case for the influence of naming and verbal behavior on equivalence class formation (Horne & Lowe, 1996) though it does not demonstrate the necessity or sufficiency of naming for equivalence class formation.

The effect of stimulus meaningfulness on the formation of equivalence classes as investigated by Lyddy, Barnes-Holmes, and Hampson (2000) reported a different trend. The experiment was done using nonsense syllables rated as high or low in meaningfulness (m) on the Glaze and Krueger rating scales. A low rating was defined as 40 or below on the Glaze scale and 60 or below on the Krueger scale. A high rating was 70 or above on the Glaze scale and 80 or more on the Krueger scale. Thirteen undergraduates participated in the study and were assigned two experimental procedures; six in procedure 1 and seven in procedure 2. There were several combinations of high and low m stimuli as samples and comparisons in both procedures but whiles procedure 1 had an "all high" class, procedure 2 had an "all low" class. Thus, in procedure 1 for instance, A1-B1 and A1-C1 were both high and so made the derived relation B1-C1 also high-high (H-H). The opposite was true for procedure 2. Results from the study showed:

(a) that, there were more errors with stimuli sets higher on the meaningfulness scales than with low ratings. Thus, performance was better with the use of stimuli lower in meaningfulness; (b) there were more errors when the sample and comparisons differed in terms of their m ratings (e.g. H-L or L-H), and less errors when sample and comparison had same ratings (L-L or H-H). Discussing the first finding, the authors suggested that the selection of stimuli low in meaningfulness may be advantageous because the meaningful stimuli which by definition have more extra-experimental associations may produce conflict with the training and thus, interfere with those associations. This finding is consistent with some studies that used real words as stimuli (e.g., Plaud, 1995).

The discussion so far has followed a certain trend, thus, the use of familiar or meaningful stimuli being influential in facilitating responding in accord with equivalence. It should however be mentioned that not all of the papers have reported this trend. Smeets and Barnes-Holmes (2005) is one typical example of an adverse finding with the use of familiar pictures in equivalence research. They trained sixteen children to form two 5-member classes in two different training structures, OTM and MTO. They used both abstract and familiar picture stimuli as nodes so that they could investigate the influence or probability of responding in accord with equivalence by using either abstract or familiar pictures as nodes. Results from the responding of the children suggested that those who had the abstract condition readily responded in accord with equivalence than their counterparts who had familiar picture stimuli as nodes.

Arntzen and Lian (in press) reporting higher yields on equivalence with the use of familiar pictures than with abstract stimuli, discussed some issues that could have accounted for the findings of Smeets and Barnes-Holmes (2005). First, they argued that the kind of instructions given to participants during the first two trials in the second phase of the experiment taught the participants to name the stimuli, which has been shown during equivalence tasks to have a facilitating effect on responding in accord with equivalence (e.g., Mandell & Sheen, 1994). Another issue raised as a possible reason for such contrary findings was the use of manual MTS arrangements as against the computer administered stimuli employed by Arntzen and Lian (in press). The argument is that manually administering the stimuli provides weaker experimental control compared to when it is computer administered, and could actually be influential in the participant's responding. The last issue was that, Arntzen and Lian (in press) arranged a three-choice MTS task while Smeets and Barnes-Holmes (2005) used a two-choice MTS format.

The contradiction in the results makes it very relevant for further experiments to be conducted for more analysis into the findings, and especially a systematic replication of the Smeets and Barnes-Holmes (2005) study conducted taking into account the questions raised regarding methodology by Arntzen and Lian (in press). One other direction for future experiments is how abstract stimuli can actually be trained to become meaningful to participants prior to the equivalence test to investigate whether or not it will have a facilitating effect as far as responding in accord with equivalence is concerned. It is an area which has not been reported in the literature so far and thus has influenced the experiment reported in the empirical paper of this thesis that follows.

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Discriminative Functions of a Meaningful Stimulus

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Abstract

The likelihood of equivalence class formation is enhanced with the use of MTO and OTM training structures as well as the use of a simple-to-complex training and testing protocol. Using linear series training structure and large multi-nodal classes reduces the likelihood of equivalence class formation. Identifying the true variables that enhance the formation of equivalence classes can be made very effective by requiring participants to form large multimodal classes. Studying the effects of the “meaning” of a stimulus on equivalence class formation, therefore, the current study used a linear series training structure and required participants to form three 5-member multi-nodal classes to help identify whether the “meaningfulness” of a stimulus is the true enhancing variable. Three experimental conditions were introduced with the C-stimuli being the difference among them. The first condition had abstract stimuli only; the second condition had the same set of stimuli but meaningful pictures as C-stimuli, and the third condition had abstract stimuli only but had pretraining with the C-stimuli. No participant responded in accord with the experimenter defined classes after using only abstract stimuli. 8 out of 10, and 4 out of 10 in the meaningful picture as C-stimuli and acquired-function conditions respectively responded in accord with experimenter defined classes. Reaction time data also showed a typical pattern, in which there was an increase from training to test and a decrease during testing. Possible functions of the meaningful stimulus are also discussed.

Keywords: Stimulus meaningfulness, Stimulus equivalence, Reaction time, Linear series.

Discriminative Functions of a Meaningful Stimulus

After training a series of conditional discriminations, if one's responding to derived unreinforced relations are seen to have the properties of reflexivity, symmetry, and transitivity, then the person's responding demonstrates stimulus equivalence (Sidman & Tailby, 1982). Thus, if one is taught two conditional discriminations, AB and BC (i.e., select comparison B when sample A is presented, then select comparison C when sample B is presented), stimulus equivalence will be demonstrated if the participant's responding is in accord with tests of reflexivity, symmetry, and transitivity. The test for reflexivity requires that without further reinforcement, the participant matches each of the stimuli to itself. Sidman (1992) calls the test for reflexivity generalized identity matching. For symmetry, the participant's responding must show the conditional relations to be bidirectional. The sample and comparison should be interchangeable in function, such that samples function effectively as comparisons with former comparisons as samples. So the relations BA and CB should emerge without further reinforcement. Lastly, transitivity requires that the relation AC emerges though they had not been paired in training, and without reinforcement. All of the stimuli could be said to be in one equivalence class and be mutually substitutable. Hence stimulus equivalence is synonymous with stimulus substitutability (Green & Saunders, 1998).

Stimulus equivalence research have been conducted with typically developed children and adults and (e.g., Arntzen & Lian, in press; Holth & Arntzen, 1998), children and adults with developmental disabilities (Arntzen, Halstadtro, Bjerke, & Halstadtro, 2010; Rehfeldt & Dixon, 2005) and have been conducted using different protocols (Imam, 2006) and different training structures (Arntzen, Grondahl, & Eilifsen, 2010; R. R. Saunders & Green, 1999). Different modalities of stimuli have also been used. Studies has been reported using olfactory stimuli

(Annett & Leslie, 1995), tactile (Belanich & Fields, 1999) and visual (e.g., Arntzen, 2004; Arntzen & Lian, in press; Sidman & Tailby, 1982). Visual stimuli reported could be abstract stimuli (Sidman & Tailby, 1982) or familiar or meaningful pictures (Arntzen, 2004; Arntzen & Lian, in press). Stimulus equivalence have been found to be influenced by training structure (Arntzen & Holth, 2000a; Arntzen & Vaidya, 2008), number of nodes of the equivalence class (Fields & Verhave, 1987), the instruction used (Arntzen, Vaidya, & Halstadtro, 2008), and the meaningfulness or familiarity of the stimuli used (Arntzen & Lian, in press; Bentall et al., 1993; Dickins et al., 1993; Holth & Arntzen, 1998; Mandell & Sheen, 1994).

Saunders and Green (1999) used term *training structure* to refer to 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. They are one-to-many (OTM), many-to-one (MTO), and linear series (LS). In OTM, a single stimuli serving as a sample is trained to at least two comparisons, hence the name “*sample-as-node*” (K. J. Saunders et al., 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). Even though the original articles of Sidman did not suggest a difference in equivalence outcome as a result of the training structure employed, some papers have come to such conclusions. Some papers have found MTO to be the most effective training structure, i.e., training with MTO structure has produced higher yields on equivalence (e.g., Arntzen & Vaidya, 2008; K. J. Saunders et al., 1993). Others have found higher yields with OTM (Arntzen, 2004; Arntzen & Holth, 2000a). However, LS has always been consistently found to be the least effective. This finding about the LS training structure has been explained by the effects of the “number of nodes” used in the experiment, which can only be studied when using a linear series training structure (Fields, Adams, & Verhave, 1993)

A node can be defined as a stimulus that is connected to at least two other stimuli. Fields and his colleagues have found that increasing the number of nodes in an equivalence class increases ‘‘associative distance’’ and results in a decrease in performance accuracy on tests for emergent relations (Fields et al., 1993). 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 describe 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).

Meaning and nameability of stimuli which are potential class members have been identified as properties that may influence the formation of equivalence classes (Arntzen, 2004; Arntzen & Lian, in press; Bentall et al., 1993; Dickins et al., 1993; Holth & Arntzen, 1998; Lyddy et al., 2000; Mandell, 1997; Mandell & Sheen, 1994). In Arntzen and Lian (in press) sixteen children were trained to form three 3-member classes using an MTO training structure in two conditions. Eight of them were trained first with an all abstract stimuli set, and then to a condition where new abstract stimuli were the samples and 3 pictures were the comparisons and nodes as well. The second half of the participants had training in the opposite sequence. The paper reported higher yields on responding in accord with equivalence in the conditions with pictures as nodes than the conditions with abstract stimuli only, irrespective of the sequence of training. The reaction time to criterion saw an increase from baseline trials to equivalence test trials than to symmetry tests but the increase was higher in the conditions with all abstract stimuli than that with pictures as nodes. Bentall et al. (1993) have reported a similar finding.

The use of meaningful stimuli has not always been found to be effective in terms of responding in accord with equivalence. Smeets and Barnes-Holmes (2005) is one such typical example of an adverse finding with the use of familiar pictures in equivalence research. They trained sixteen children to form two 5-member classes in two different training structures, OTM and MTO. They used both abstract and familiar picture stimuli as nodes so that they could investigate the influence or probability of responding in accord with equivalence by using either abstract or familiar pictures as nodes. Results from the responding of the children suggested that those who had the abstract condition readily responded in accord with equivalence than their counterparts who had familiar picture stimuli as nodes. Questions have been asked of this finding (Arntzen & Lian, in press), but it is obvious that there are contradictory reports on the effect of familiar stimuli in equivalence class formation. Plaud, Gaither, Franklin, Weller, and Barth (1998) investigated the formation of equivalence classes using three different stimuli sets as sexually explicit words (naked, condom, erotic, lover, passion and genital), sexually ambiguous words (bush, cream, score, nuts, french, beaver), and neutral words (relish, idolize, feather, sailor, gutter, speech). Results from the study showed that, participants had more training trials to criterion, made more errors, and took more time to respond in the sexually explicit stimulus condition compared with the sexually ambiguous and neutral words conditions. This indicates an inhibitory effect of meaningful stimulus (sexually explicit words) on equivalence class formation. The sexually explicit words in the experiment, did not easily generalize to other sexually explicit words. A possible reason for this finding as suggested by Sidman (1994) is that, the use of stimuli which are familiar to the subjects may confound the relations resulting from the explicitly arranged experimental conditions with relations following from the subjects' preexperimental history.

Improved performance during testing, referred to as “delayed emergence” (Sidman, 1994) has been reported in many papers (e.g., Bush, Sidman, & de Rose, 1989; Dube, Green, & Serna, 1993; Fields & Garruto, 2009; Holth & Arntzen, 1998; Sidman, 1994; Sidman et al., 1985). Thus, participants have been reported to have experienced the tests several times before responding in accord with experimentally defined classes suggesting that learning took place during the testing of emergent relations. Sidman (1994) suggested that, delayed emergence may occur because stimuli can belong to other classes in addition to the experimentally established classes being tested. It could also be as a result of the participant's extraexperimental history (Sidman, 1992). Previously untrained simple discriminations could also develop over the course of testing due to (a) the additional exposure to training trials, (b) the juxtaposition of test trials that include those discriminations with training trials, or (c) both (R. R. Saunders & Green, 1999).

Reaction time to comparison stimuli has been identified as a very important variable in derived relations researches (Dymond & Rehfeldt, 2001) and have been investigated by a number of studies (Arntzen, 2004; Arntzen, Grondahl, et al., 2010; Bentall et al., 1993; Bentall, Jones, & Dickins, 1998). A characteristic pattern of reaction time to comparison stimuli has been found, with an increase from the last training trials to the first trials during testing, and then a decrease in the last test trials, thus, a dip down pattern in responding (Arntzen, 2004; Bentall et al., 1993). The increases in the reaction time to comparison stimuli during the test trials are found to be more pronounced for equivalence trials compared to symmetry trials (e.g., Arntzen, Grondahl, et al., 2010). Reaction time data could be used to further study the meaningfulness of the stimuli used in the experiment, with predictions that, it will be shorter with the use of familiar pictures, than with abstract stimuli.

In the current study, the discriminative functions of meaningful stimuli in equivalence class formation were investigated using a linear series training structure, to establish three 5-member equivalence classes. Thirty participants were randomly assigned to three different experimental conditions (10 participants in each), namely: (a) all abstract-stimuli condition, (b) pictures as C-stimuli, and (c) acquired-function condition, with the difference among the conditions being the C-stimuli in all the classes for all conditions. The purpose of the study was to investigate if (1) the stimuli sets used in each of the conditions will affect responding in accord with equivalence, and (2) the different sets of stimuli used will influence the number of trials to criterion during training of conditional discriminations. The study also investigates whether there is any instance of delayed emergence, and also studies the patterns of reaction times to comparison stimuli from training to test trials for all the conditions.

Method

Participants

Thirty adults comprising of 27 college students and 3 employees of the college (10 males and 20 females) between the ages of 19 and 45 (average age is 26.4) served as participants in the current experiment, as shown in Table 1. They were recruited through personal contacts and their participations were voluntary. All participants were naive in terms of knowledge about stimulus equivalence and relevant research methodology. Participants were made to read and sign an informed consent form prior to their participation and were randomly assigned to three experimental conditions and exposed to different sets of stimuli. Before the beginning of the experimental sessions, participants were given a written informed consent form that contains all the relevant information about the experiment including the fact that it is within the field of behavior analysis and that at any point in the experimental sessions, participants were free to withdraw from the experiment without any negative consequences. Participants were also made to understand that they were absolutely anonymous and thus, their names were not needed, and also their participation in the study is strictly for academic purposes. Lastly, there were no known harmful effects for participating in the study. After that, participants were asked if they had any questions and were addressed accordingly before they signed the informed consent form. The experiment was followed by a debriefing session, where the participant was informed about the purpose of the experiment, and shown the results file from their own experiment. The experimenter attempted to answer all questions the participant had at this stage. Lastly, an introductory article on the subject of stimulus equivalence was given out to every participant.

Setting and Apparatus

Two small and identical experimental rooms approximately 2m x 2m, furnished with a table and two chairs were used for the experiments. An HP Compaq nc6320 portable personal computer with 1828 MHz Intel Centrino® processor and a 15 inch screen size was used for the presentation of stimuli. Sessions for training and testing of conditional discrimination for all participants were conducted with a software program version 3.12 made by Psych Fusion Software in collaboration with Professor Erik Arntzen, which controlled the presentation of all stimuli and also made all recordings of responses by participants in a matching-to-sample (MTS) format. Participants in the third condition, however, had 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.

Stimuli

Different sets of stimuli were used depending on the experimental condition of participants. The significant difference in the stimuli set used was the C stimuli in the sets. In Condition 1, participants had all 15 stimuli as abstract as shown in the top panel of Figure 1. Condition 2 had identical set of stimuli as Condition 1 except that the C stimuli were familiar pictures (see lower panel of Figure 1). In Condition 3, the participants had the same set of stimuli as Condition 1 after some preexposure with the C stimuli. The abstract stimuli were printed in black and the picture stimuli in colours, both on a white background. Small plastic-laminated pictures of size 3.8cm x 3.8 cm were made from the stimuli to be used in experiment and given to participants to categorize them. The size of the touch sensitive areas on the screen was 8.6cm x 3.7 cm. The distance from the nearest edge of the sample to the nearest edge of the comparison is 4.7cm. The distance between the comparisons in width is 12 cm and 12.9cm in length.

Design

Participants were randomly assigned to three different conditions; (i) Condition 1- All abstract stimuli condition; (ii) Condition 2- C stimuli as familiar pictures whiles others were abstract (same as Condition 1), and (iii) Condition 3- all abstract stimuli as Condition 1 but with preliminary exposure/training with the C stimuli. The difference among the groups is the C-stimuli with the first condition using abstract stimuli only, the second condition having familiar/meaningful stimuli as C-stimuli, whiles the Cs in the third condition will be abstract stimuli given discriminative functions. The purpose is to investigate if the discriminative functions acquired by the abstract stimuli will facilitate equivalence class formation.

Procedure

The participant is informed that he or she is required to respond to certain stimuli on the screen of a computer with mouse clicks and that the duration of the experiment is approximately one and a half hours, but also depends on the accuracy of their responses. The participants were given the small plastic-laminated pictures of the stimuli to be used in experiment (3.8cm x 3.8cm), and told to categorize them. After the pre-experimental categorizations of the stimuli for the participant has been documented by the experimenter, the participant is made to sit in front of the computer and presented with the following instructions on the computer screen, except participants in Condition 3 (Acquired-function condition) who have to do same only after a successful pre-exposure with the C-stimuli to be used in the MTS experiment (to be described later):

> 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!

The session begins with the appearance of a sample stimulus in the middle of the computer screen. Presentation of stimuli during training and testing was done through a simultaneous protocol. Thus, responding to the sample stimulus by a mouse click on it is 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 responses, in the form of choosing the correct comparison stimulus according to the experimenter designated classes the words *correct*, *super*, *excellent* and so on appeared on the screen. Any other response produced the word *wrong* on the screen. The feedback duration was 1 second and the inter trial interval was 0.5 seconds. The experiment always required a response to the sample stimulus for the presentation of the comparison stimuli and the mouse position was reset above the sample stimulus after each trial.

The experiment employed a linear series training structure, where participants were taught to match the experimental stimuli in the form A→B →C→D→E such that A1 was taught to be matched to B1, B1 to C1, C1 to D1, and D1 to E1, and in this same way for A2 and A3. This was done by presenting the relations on a serialized basis, where A→B (1-3) were first presented in the form, A1<u>B1</u>B2B3, A2B1<u>B2</u>B3, A3B1B2<u>B3</u>, where the alphanumeric codes presented first are samples, while underlined alphanumeric codes indicate the experimenter defined “correct” comparisons. All training trials were presented randomly with all possible trials appearing three times in a block, giving us 9 trials per block in the first 4 blocks of training. Mastery criterion for each training trial type through to the testing was set to 90%. A total number of 9 correct trials were therefore required to proceed to the next in the first 4 training blocks. Participants repeated each block till the mastery criterion was met. There was an equalizing block option that required that based on the number of trials needed by the participant to pass the first training trial type A→B participants will have to complete the same number of trials for each subsequent training trial types. All trial types were then mixed in the next block with all relations present.

Following the baseline training of all relations, all the trial types were mixed in a training block consisting of 36 trials with feedback fading from 100% to 75% for the next block, then to 50%, 25%, and 0% for the subsequent blocks. The mastery criterion was 90% correct responses in each block. The final fading block was followed by a test block where no feedback was delivered. The test block consists of 180 trials in all (36 baseline trials, 36 symmetry trials, 54 1-Node trials, 36 2-Nodes trials, and 18 3-Nodes trials) randomly intermixed. Three trials each of the following trial types made up the 36 baseline trials: A1B1B2B3, B1C1C2C3, C1D1D2D3, D1E1E2E3, A2B1B2B3, B2C1C2C3, C2D1D2D3, D2E1E2E3, A3B1B2B3, B3C1C2C3, C3D1D2D3, and D3E1E2E3. 3 trials each of the following also made up the 36 symmetrical trials: B1A1A2A3, C1B1B2B3, D1C1C2C3, E1D1D2D3, B2A1A2A3, C2B1B2B3, D2C1C2C3, E2D1D2D3, B3A1A2A3, C3B1B2B3, D3C1C2C3, and E3D1D2D3. 54 1-Node trials comprising of 3 each of the following: A1C1C2C3, B1D1D2D3, C1E1E2E3, C1A1A2A3, D1B1B2B3, E1C1C2C3, A2C1C2C3, B2D1D2D3, C2E1E2E3, C2A1A2A3, D2B1B2B3, E2C1C2C3, A3C1C2C3, B3D1D2D3, C3E1E2E3, C3A1A2A3, D3B1B2B3, and E3C1C2C3. 3 each of the following trials constituted the 36 2-Nodes trials: A1D1D2D3, B1E1E2E3, D1A1A2A3, E1B1B2B3, A2D1D2D3, B2E1E2E3, D2A1A2A3, E2B1B2B3, A3D1D2D3, B3E1E2E3, D3A1A2A3, and E3B1B2B3. Lastly, 3 each of the following trials made up for the 18 3-Nodes trials: A1E1E2E3, E1A1A2A3, A2E1E2E3, E2A1A2A3, A3E1E2E3, and E3A1A2A3. In each of the trials, participants were expected to match the samples (the alphanumeric codes presented first) to the correct comparisons (the underlined alphanumeric codes).

The software automatically took care of records of all data including the number of training trials; reaction time to sample and comparison stimuli, whether or not participant chose the correct/incorrect comparison choice, and whether or not feedback was delivered. A summary of symmetry and equivalence tests were also provided by the software.

Before going through the procedure described above, participants in the acquired-function condition (Condition 3) were put through two different simple discrimination training. The first discrimination training was done to establish the C-stimuli (C1, C2, and C3) to be used in the subsequent MTS experiment as familiar stimuli. There were five phases in this part of the experiment. Phases 1was ordinary simple discrimination training between the C's and X's; phase 2 between the C's and Y's; phase 3 between the C's and the Z's whiles phase 4 is training with all the previous phases together. In each of these phases there was training of all trials types from the beginning, i.e., concurrent training. Each phase consisted of 10 trials of each trial type randomly presented. However, 10 consecutive correct trials were required to introduce the next phase. Responses to the C's were reinforced, while responses to all the other stimuli were followed by a blank screen. All other stimuli used here, apart from the C stimuli were not used in the MTS training and testing afterwards. Phase 5 was a test phase and no reinforcement was delivered through to the tenth consecutive correct trial to end this part of the experiment. Failure of participants to get 10 consecutive correct trials before all trial types are presented in each phase will result in the experimenter repeating that phase. The experimenter had to manually count the number of consecutive correct trials in each phase.

Successful completion of this part of the experiment meant progress to the next simple discrimination task, this time among the C-stimuli. Here, each of the C stimuli were put on different FR schedules, C1 on FR 3, C2 on FR 6, and C3 on FR 9. 10 trials of each schedule were randomly presented. At each trial, one of the stimuli appeared on the screen and participants were required to press on it by 3, 6, or 9 times when C1, C2, or C3 is presented respectively. Following the number of times the participant presses on the stimulus, the participant pressed on the END button on the computer keyboard for feedback. Correct responses were followed by the word "*correct*" appearing on the screen. Any other number of responses apart from the experimentally defined ones followed by the END button produced an incorrect feedback. Again, 10 consecutive correct trials were required to master the training, and the experimenter had to manually count the number of correct responses. Failure of the participant to meet this criterion before all the trials are presented meant the participant repeats the training.

The whole training phase was divided into two phases: acquisition and maintenance phases. The acquisition phase represents the beginning of the training trials through to the end of the 100% probability of feedback whiles maintenance represents the beginning of the 75% probability of feedback to the end of the 0% probability of feedback.

Definition of responding in accord with stimulus equivalence

After the test, a participant's performance is considered to be in accord with stimulus equivalence, if that participant "correctly" matched at least 90% of all the equivalence test trials (including 33 out of 36 for symmetry trials, 49 out of 54 for 1-Node trials, 33 out of 36 for the 2-Nodes trials, and 17 out of 18 for the 3-Nodes trials).

At the end of the experiment, the small plastic-laminated pictures of the stimuli set used in the experiment were given to the participant to categorize them again and the categorization written down by the experimenter.

Results

Number of training trials

Once participants have reached the criterion to progress through the phases to the test phase, they needed no extra trials to reach the criterion so the most important variable as far as the number of trials is concerned is the number of training trials needed for each participant to progress into the testing phase. For participants in the all abstract condition, the number of training trials was very high as compared to the other conditions. Participant # 4111 had the least number of trials in that condition with 432 trials, whilst the highest was 1296 trials for participant # 4109.

For participants in the Pictures as C-stimuli condition, 2 participants, # 4114 and # 4110 had the least number of training trials which was 288. Apart from participant # 4136, with the highest number of training trials with 900. In the acquired-function condition, the least number of training trials was 288, by participant # 4120. Participant # 4125 had the highest number of training trials which was 1116 trials. The other participants had a much lower number of training trials than participants in the all abstract stimuli condition (see Table 3).

At the group level, the number of training trials to establish baseline relations was much higher under the all abstract stimuli than the other two conditions. The mean number of trials to criterion for those in the all abstract condition was 716.4, whilst the mean number of training trials for participants under the pictures as C-stimuli was 442.8, and that for those under the acquired-function condition was 504.

The baseline trials were divided into an acquisition phase and a maintenance phase for all participants with the first block of training through the fifth block (from the training of AB trials to the end of 100% probability of feedback in the mixed block) constituting the acquisition phase, whilst the beginning of 75% probability of feedback (sixth block) to the end of 0% probability of feedback (ninth block) constitutes the maintenance phase. For the acquisition phase, median scores for the total number of trials for participants in the all abstract condition was the highest among the conditions with 522 trials. The median total number of trials for participants in the pictures as C-stimuli condition was 252, whilst that for the acquired-function condition was 288. The same trend was shown in the number of errors in that phase with those in the all abstract condition having the highest with 112.5 errors. The pictures as C-stimuli and the acquired-function conditions had fewer errors compared to the all abstract condition with 30.5 and 45 errors respectively.

Median number of trials for the maintenance phase show that there were no extra trials needed to meet the criterion with the median of the total number of trials for all the conditions as 144 trials, the minimum number of trials required. However, median for the total number of errors suggest few errors for all the conditions with the all abstract and the pictures as C-stimuli conditions recording 1 error each, and the acquired-function condition recording the least of 0.5 trials.

Emergent relations

As shown in Figure 3, in the abstract stimuli, no participant responded in accord with stimulus equivalence. Eight participants responded in accord with equivalence in the pictures as C-stimuli condition and four in the acquired-function condition responded in accord with equivalence. In the all abstract condition, it was only participant # 4109 who responded in accord with symmetry (see Table 3). Otherwise, none of the participants in that condition responded according to experimenter-defined classes. As Table 3 shows, all eight participants that responded in accord with equivalence in the picture as C-stimuli condition also responded in accord with symmetry, whilst five participants responded in accord with symmetry in the acquired-function condition. Only participants # 4109 in the all abstract condition and # 4120 in the acquired-function condition responded in accord with symmetry but not equivalence. It must also be noted that participant # 4109 who was the only one who responded in accord with symmetry in the all abstract condition had the highest number of trials in that condition with 1296 trials. All others who responded in accord with symmetry also responded in accord with equivalence, and also others all participants that missed out on symmetry did not respond in accord with equivalence.

Transitivity and equivalence trials were summed up as 1-node, 2-nodes, and 3-nodes because of the training structure employed and number of members in each experimentally defined class. For all the participants in all the conditions, all who responded in accord with equivalence responded to the criterion for at least one of the nodal tests. No participant in the all-abstract condition responded to criterion in any of them. As seen in Table 4, seven out of ten participants in the pictures-as-C-stimuli responded to criterion for the 1-node test, whilst four did so for the-acquired-function condition. For the 2-nodes test, eight in the pictures as C-stimuli condition responded to the criterion as against four in the acquired-function condition. For the 3-nodes, five participants responded to the criterion in the pictures as C-stimuli condition against three in the acquired-function condition. All of the eight participants who responded to the criterion on the 3-nodes also responded to the criterion for the 1-node and 2-nodes. Apart from participant # 4102, all eleven participants that responded to the criterion for 1-node also responded to the criterion for 2-nodes, but out of the eleven, only eight of them responded to the criterion for 3-nodes. Participant # 4102 was the only participant that did not respond to the criterion for 1-node but did so for the 2-nodes.

When the test trials were divided into two equal halves, no participant in the all abstract stimuli condition responded in accord with equivalence in either of the halves. For the pictures as C-stimuli condition two participants (# 4102 and # 4110) did not respond in accord with equivalence in the first half of the test trials but responded in accord with equivalence in the second half. Two participants (# 4123 and # 4120) from the acquired-function condition did not respond in accord with equivalence in the first condition but did so in the second half. Both # 4102 and # 4110 on the whole did respond in accord with equivalence, so was participant # 4123. It is, thus, clear from the data (see Table 5) that, though they did not respond in accord with equivalence in the first half of the test, they had higher yields on equivalence in that half, almost equal to the criterion. Participant # 4120 did not respond in accord to equivalence in the whole test. However, dividing the test into two halves, the participant had a much lower yield than the criterion for equivalence in the first half, but responded to the criterion in the second half.

The yields obtained with the participants in the Abstract C and the Meaningful C groups were significantly different (Fisher Exact, .007). Therefore, the inclusion of a meaningful stimulus as the middle node in an equivalence class enhanced class formation. The yields obtained with the participants in the Abstract C and the C as S^D groups were also significantly different (Fisher Exact, .033). Thus, equivalence class formation was also enhanced when an equivalence class contained a middle node that had acquired a discriminative function prior to class formation. Although a smaller percentage of participants formed classes in the Acquired-function group than in the meaningful stimulus group, the difference in yields was not significantly different (Fisher Exact, 0.35). The trend, suggests that only part of the enhancement effect engendered by meaningful stimuli as nodes can be accounted for the presumed discriminative functions served by meaningful stimuli.

The individuals who formed experimenter-defined classes acquired the baselines in 38% fewer trials than did those who did not form the classes, a statistically significant difference, $t=2.348$ $df=27$, $p=.0264$). An r^2 of .36, calculated using trials to acquire the baseline relations across participants who did and did not form classes, indicated that the speed of acquiring the baseline relations was a modest predictor of class formation.

Reaction time

For all of the conditions, the median mean median reaction time to comparison stimuli increased from the last five baseline trials to the first five baseline trials during testing (see Figure 4). Reaction time to comparison for the first five test trials in all the conditions had a common pattern, with gradual increases in reaction time from the baseline trials, to symmetry, through 1-node to 2-nodes, before reducing on the 3-nodes. The increases in the first five test trials were however higher in the all abstract stimuli condition compared to the other two conditions. For all the five last test trials, there were decreased reaction times to comparison compared to the first five test trials in all the conditions with the pictures as C-stimuli and the acquired-function condition recording a gradual increase from the last five baseline test trials through to the last five test trials for the 3-nodes. For the acquired-function condition, however, there was a decrease from the last five baseline test trials to the last five symmetry trials, then a small increase to the last five 1-node trials before small increase through the last five 2-nodes trials to the last five 3-nodes trials.

On the whole, the typical pattern for reaction time to comparison was seen in responding in all of the conditions, i.e., there was a decrease in reaction time to comparison stimuli from the first five test trials to the last five test trials. Figure 4 shows that the reaction times to comparison were slightly higher in the all abstract stimuli condition as compared to that of the other conditions.

Categorization of stimuli

As shown in Table 6, the pre-experimental sorting of stimuli of all of the participants suggest that no participants knew before hand the experimentally defined classes prior to the experiment. Post experimental sorting by three participants (# 4101, # 4102, and # 4103) are unavailable because of a software problem encountered during the start of the experiments. The sessions with those participants had already ended but the experiment was still running so after some time, the participants opted to withdraw, so it was not necessary to have subjected them to the post experimental sorting. However, going through the results files after they had long left the experimental room revealed that they had successfully gone through the experiment. For the post experimental sorting, all participants that did not respond in accord with equivalence did not also get the sorting according to the experimentally defined classes. Participant # 4113 got one class rightly sorted but missed out on the others. Participant # 4120 who on the whole did not respond in accord with equivalence got the sorting correctly (see Table 6). However, it is to be noted that when the test trials were divided into two equal halves, participant # 4120 responded in accord with equivalence in the second half (see Table 5).

Discussion

The purpose of the present study was to investigate the effects of discriminative functions of meaningful stimuli on equivalence class formation. Results from the experiment show that participants in the pictures as C-stimuli condition and the acquired-function condition had fewer trials to criterion compared to participants in the all abstract-stimuli condition. Eight out of ten, and four out of ten participants responded in accord with equivalence in the pictures as C-stimuli and the acquired-function conditions respectively, as against none out of ten in the all abstract-stimuli condition. Reaction time to comparison was also found to be shorter in pictures as C-stimuli and the acquired-function conditions than the all abstract-stimuli condition.

In the current study, the number of trials to criterion was found to be lower with the condition with familiar pictures as nodes and the acquired-function condition than for the abstract stimuli only condition. The median number of trials to criterion and the number of errors recorded during the acquisition phase for the all abstract- stimuli condition was much higher than the other conditions. This is to say that, the results are in favor of relative meaning of stimuli being very effective in the training of conditional discriminations. It is a finding that is consistent with several papers (e.g., Arntzen, 2004; Arntzen & Lian, in press; Bentall et al., 1993; Bentall et al., 1998; Dickins et al., 1993; Mandell, 1997; Mandell & Sheen, 1994). A contradictory finding has been reported by Plaud et al. (1998). In that study, the authors investigated the formation of equivalence classes using three different stimuli sets as sexually explicit words, sexually ambiguous words, and neutral words. Results from the study showed that, participants had more training trials to criterion, made more errors, and took more time to respond in the sexually explicit stimulus condition compared with the sexually ambiguous and neutral words conditions. This is indicative of an inhibitory effect on equivalence class formation after using a meaningful stimulus. Various reasons can account for this, such as; using stimuli which may be familiar to the subjects could confound the relations due to the explicitly arranged experimental conditions with relations following from the subjects' preexperimental history. Thus, meaningful stimuli might conflict with trained relations. It is important that further experiments are conducted on this issue since there are divergent findings. For instance, a good dimension of stimuli used to study meaningfulness could be whether or not it is namable.

The results suggest a facilitating effect of meaningful stimuli in terms of responding in accord with equivalence. No participant responded in accord with equivalence when they were exposed to abstract stimuli only, but there were significantly higher yields on responding in accord with equivalence after training with familiar pictures and also after establishing a discriminative function for abstract stimuli which are used as nodes in the experiment. This is consistent with other studies (Arntzen, 2004; Arntzen & Lian, in press; Holth & Arntzen, 1998). A contradictory trend of responding in accord with equivalence with the use of familiar or meaningful stimuli have been found (e.g., Smeets & Barnes-Holmes, 2005). In that study, sixteen children were trained to form two 5-member classes in two different training structures, OTM and MTO. They used both abstract and familiar picture stimuli as nodes so that they could investigate the influence or probability of responding in accord with equivalence by using either abstract or familiar pictures as nodes. Results from the responding of the children suggested that those who had the abstract condition readily responded in accord with equivalence than their counterparts who had familiar picture stimuli as nodes. Questions have been raised of this findings and important issues discussed as well (Arntzen & Lian, in press). Possible reasons why the conditions with meaningful stimuli as nodes are found to be facilitating could be that, first, a meaningful stimulus can serve as a cue/prompt and function as a discriminative stimulus for many different responses. Responses evoked by the C stimulus would also be evoked by the other stimuli in the newly emergent equivalence class without further training.

Secondly, a meaningful stimulus can function as a member of at least an isolated conditional discrimination. In that sense, the formation of class is more likely when it is linked to another circumstance where the C-stimulus was not used as a member of a conditional discrimination since the other members of the class would automatically become related to the entire members related to the C in a conditional discrimination. Third, a meaningful stimulus may function as a member of a semantic network containing many other words and referents. In that way, the formation of a new class will involve an expansion of an already existing class where the meaningful stimulus acts as a node to link the new class with the semantic network of which it is already a member.

The difference in conditions in respect to responding in accord with equivalence, especially between the all abstract stimuli only condition on one hand and the pictures as C-stimuli and acquired-function conditions on the other hand could be explained using the functions a meaningful stimulus could play in equivalence class formation discussed above. The relative difference in responding in according with equivalence could also be explained by the fact that the C-stimuli in the acquired-function condition have a very short history compared to the familiar pictures in the pictures as C-stimuli condition.

Data from the experiment suggests a significant decrease in performance accuracy with an increase in number of nodes. For all participants who did not responded in accord with equivalence, however, the effect of the number of nodes in performance accuracy was more pronounced from than participants who responded in accord with equivalence. This general finding is consistent with the *nodal distance* effect reported in earlier studies (Arntzen & Holth, 2000b; Fields et al., 1993; Fields & Verhave, 1987; Fields & Watanabe-Rose, 2008). It is however contradictory to the reinforcement-contingency explanation of equivalence class formation that suggests that performance accuracy and speed should be not be a function of the nodal number since there is equal histories of reinforcement (Sidman, 1994). Imam (2006) reports of findings consistent with the prediction of equal accuracy and speed regardless of the nodal number. In that experiment, Imam controlled for the number of trials by equalizing trials across baseline and the emergent relations and concluded that response accuracy did not decrease as a function of nodal number. For participants who responded in accord with equivalence, the effect of number of nodes was not more pronounced. The effect could be seen from the distance between the second node and the third node but not from the first node to the second node since all those who responded to criterion for the 1 node also responded to criterion for the 2 nodes, and even more participants did so in the 2 nodes than the 1 node. A reason for the almost equal accuracy across the number of nodes could be attributed to the effects of the meaningful stimuli used in the experiment by those participants.

Splitting the test trials into two equal halves, there were instances of improved performance from the first half to the last half. The responding of participants # 4102, #4110, #4123, and #4120 are typical examples. This is a finding consistent with the notion of delayed emergence (Dube et al., 1993; Fields & Garruto, 2009) and more especially abruptly with repeated testing (Bush et al., 1989). Devany, Hayes, and Nelson (1986) found that a history of differential reinforcement for consistent responding may account for the delayed emergence of equivalence. The participant’s correct responding to previously untrained simple discriminations could also develop over the course of testing due to the additional exposure to training trials or the juxtaposition of test trials that include those discriminations with training trials or both of the two (R. R. Saunders & Green, 1999).

Reaction time data from this study has replicated the findings of earlier studies with a pattern where there is an increase from training to the test and a decrease during the test (Arntzen, 2004; Arntzen, Grondahl, et al., 2010; Holth & Arntzen, 1998). The study also suggests a more profound increase in reaction time for equivalence trials than symmetry trials. This is consistent with the findings of earlier papers (e.g., Arntzen, Grondahl, et al., 2010). The pattern has been described as a "dip down" (Bentall et al., 1993). Fields and Verhave (1987) suggests that response accuracy decreases with an increase in number of nodes. Reaction time data for participants in the all abstract-stimuli condition suggests otherwise. There was a trend of shorter response time as the number of nodes increases. This can however be explained by the *recency effect,* which suggests that given a list of items to remember, we will tend to remember the last few things more than those things in the middle (Catania, 2007).

In the pre-experiment categorization of the stimuli by all of the participants, there were no suggestions of the possibility of the stimuli being pre-associated before the experiment since no participant categorized them according to the experimenter defined classes. In the post experiment categorization, all participants who responded in accord with equivalence in the experiment (except the one missing) categorized the stimuli according to the experimenter defined classes. One participant who did not respond to equivalence initially, but found to display delayed emergence after repeated testing did the post experiment categorization according to the experimenter defined classes. The data on the post-experiment categorization show that there is more Class 1 categorization than Class 2 and Class 3 categorization. This may suggest that the class one was formed more easily than any other. The stimuli categorization tasks should however be considered differently from the test for stimulus equivalence. A possible question that could be asked of the accuracy in the post experiment categorization could be that, the stimuli set were presented together at the same time and thus made it possible for participants to scan it back and forth.

Though the findings are generally consistent with some studies on the use of meaningful/familiar stimuli (e.g., Arntzen, 2004; Arntzen & Lian, in press), some procedural questions have arisen and should therefore direct further research. For instance, there is a difference in number trials between the conditions due to pretraining in the acquired-function condition and could be argued to have accounted for the difference in equivalence outcomes between that condition and the abstract stimuli condition in particular. Therefore, in one experiment we can have the number of trials yoked and by that control for number of trials across all conditions. A second experiment could see a change in the position of the node with picture and acquired function stimulus. Thus, the difference between the conditions could be moved to a different position, for instance, the A-stimuli or E-stimuli, and the effects on responding in accord with equivalence investigated. New experiments could also investigate equivalence class formation as a function of class size, where the members in the three classes could be extended from five to six for instance. Lastly, an experiment could be conducted using the other training structures, OTM and MTO to compare the effects of the nodal stimulus as abstract, picture, and acquired function when MTO and OTM are used.

In summary, this study investigated the effects of discriminative functions of meaningful stimuli on equivalence class formation. The meaning of stimuli used as nodes was identified to be an important variable that affects equivalence class formation with meaningful stimuli found to be very effective. There were few numbers of training trials and errors in the conditions with familiar pictures as nodes and the acquired-function condition than the condition with all abstract-stimuli only. Reaction time to comparison generated a common pattern with an increase from the last training trials, to the first trials in the test, higher reactions times on symmetry trials, and still higher reaction time again on 1 node, 2 nodes and 3 nodes trials.

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Table 1. The table shows the different participants, age, gender, and experimental conditions of each participant.

Participant #	Age	Gender	Condition
4109	21	Female	All abstract
4101	25	Male	All abstract
4111	24	Male	All abstract
4113	21	Female	All abstract
4103	20	Female	All abstract
4134	22	Female	All abstract
4139	45	Male	All abstract
4141	30	Female	All abstract
4142	34	Male	All abstract
4144	37	Female	All abstract
4104	20	Female	Pictures as C-stimuli
4114	25	Male	Pictures as C-stimuli
4105	21	Female	Pictures as C-stimuli
4102	27	Male	Pictures as C-stimuli
4110	22	Female	Pictures as C-stimuli
4135	23	Female	Pictures as C-stimuli
4133	23	Female	Pictures as C-stimuli
4137	28	Male	Pictures as C-stimuli
4136	25	Female	Pictures as C-stimuli
4132	45	Male	Pictures as C-stimuli
4131	22	Female	Acquired-function
4118	29	Female	Acquired-function
4125	31	Male	Acquired-function
4123	19	Female	Acquired-function
4120	20	Male	Acquired-function
4127	36	Female	Acquired-function
4117	19	Female	Acquired-function
4122	20	Female	Acquired-function
4128	30	Female	Acquired-function
4129	27	Female	Acquired-function

Table 2. The table shows the sequence of training and the test phase, the different trial types, probability of feedback, minimum number of trials and training and test criterion.

Blocks	Trials	Probability of Feedback	Min. Trials	Criterion
Training				
1. Serialized trials	A1B1, A2B2, A3B3	100%	9	9/9
2. Serialized trials	B1C1, B2C2, B3C3	100%	9	9/9
3. Serialized trials	C1D1, C2D2, C3D3	100%	9	9/9
4. Serialized trials	D1E1, D2E2, D3E3	100%	9	9/9
5. Mixed trials	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	100%	36	34/36
6. Mixed trials	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	75%	36	34/36
7. Mixed trials	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	50%	36	34/36
8. Mixed trials	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	25%	36	34/36
9. Mixed trials	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3	0%	36	34/36
Test block with Baseline trials, Symmetry, 1 Node, 2 Nodes and 3 Nodes trials randomly intermixed	A1B1, A2B2, A3B3, B1C1, B2C2, B3C3 C1D1, C2D2, C3D3, D1E1, D2E2, D3E3 B1A1, B2A2, B3A3, C1B1, C2B2, C3B3 D1C1, D2C2, D3C3, E1D1, E2D2, E3D3 A1C1, A2C2, A3C3, C1A1, C2A2,C3A3, B1D1, B2D2, B3D3, D1B1,D2B2,D3B3, C1E1, C2E2, C3E3, E1C1, E2C2, E3C3, A1D1, A2D2, A3D3,D1A1,D2A2,D3A3, B1E1, B2E2, B3E3, E1B1, E2B2,E3B3 A1E1, A2E2, A3E3, E1A1, E2A2, E3A3.	No Feedback	180	

Table 3. The table shows data for individual total number of trials and number of incorrect trials in baseline training as well as responding in accord with equivalence during the test. The acquisition phase is made up of Blocks 1-5, ie., from the training of AB trials to the end of 100% probability of fading of feedback. Maintenance constitutes Block 6 – 9, ie., 75% probability of feedback to the end of 0% probability of feedback. Numbers in bold text indicate responding equal to or more than the criterion.

		Acquisition		Maintenance		Testing	
Participant	Condition	Tot	Err	Tot	Err	Symmetry	Equivalence
4109	All abstract	1152	229	144	0	**34/36**	97/144
4101	All abstract	360	41	144	1	32/36	85/144
4111	All abstract	288	45	144	1	29/36	61/144
4113	All abstract	288	43	180	4	28/36	79/144
4103	All abstract	252	44	216	11	28/36	78/144
4134	All abstract	504	105	144	1	28/36	70/144
4139	All abstract	936	167	144	1	18/36	67/144
4141	All abstract	540	120	144	2	30/36	69/144
4142	All abstract	576	123	180	4	32/36	89/144
4144	All abstract	684	168	144	0	27/36	52/144
4104	Pictures as C-stimuli	324	62	144	3	**36/36**	**144/144**
4114	Pictures as C-stimuli	144	25	144	0	**36/36**	**144/144**
4105	Pictures as C-stimuli	288	30	144	0	**35/36**	**140/144**
4102	Pictures as C-stimuli	252	31	144	0	**36/36**	**133/144**
4110	Pictures as C-stimuli	144	10	144	1	**36/36**	**132/144**
4135	Pictures as C-stimuli	288	31	216	8	**35/36**	**142/144**
4133	Pictures as C-stimuli	252	27	144	0	**36/36**	**143/144**
4137	Pictures as C-stimuli	144	14	144	1	**36/36**	**144/144**
4136	Pictures as C-stimuli	576	147	324	27	26/36	91/144
4132	Pictures as C-stimuli	252	42	216	10	24/36	78/144
4131	Acquired-function	252	30	144	2	**35/36**	**143/144**
4118	Acquired-function	252	45	144	1	**36/36**	**144/144**
4125	Acquired-function	972	266	144	0	**36/36**	**139/144**
4123	Acquired-function	180	25	144	0	**36/36**	**134/144**
4120	Acquired-function	144	7	144	0	**35/36**	122/144
4127	Acquired-function	396	68	144	1	30/36	88/144
4117	Acquired-function	324	45	144	3	30/36	87/144
4122	Acquired-function	324	53	144	0	26/36	82/144
4128	Acquired-function	540	103	144	2	22/36	60/144
4129	Acquired-function	216	38	144	0	26/36	61/144

Table 4. The table shows the breakdown of results on all the nodal tests for all participants. Numbers in bold text indicate responding equal to or more than the criterion.

Participant #	Condition	1 Node	2 Nodes	3 Nodes
4109	All abstract	33/54	21/36	9/18
4101	All abstract	26/54	19/36	8/18
4111	All abstract	19/54	9/36	4/18
4113	All abstract	30/54	16/36	5/18
4103	All abstract	17/54	27/36	6/18
4134	All abstract	15/54	20/36	7/18
4139	All abstract	25/54	18/36	6/18
4141	All abstract	25/54	9/36	5/18
4142	All abstract	34/54	15/36	8/18
4144	All abstract	8/54	9/36	8/18
4104	Pictures as C-stimuli	**54/54**	**36/36**	**18/18**
4114	Pictures as C-stimuli	**54/54**	**36/36**	**18/18**
4105	Pictures as C-stimuli	**54/54**	**35/36**	16/18
4102	Pictures as C-stimuli	48/54	**34/36**	15/18
4110	Pictures as C-stimuli	**49/54**	**33/36**	14/18
4135	Pictures as C-stimuli	**54/54**	**36/36**	**17/18**
4133	Pictures as C-stimuli	**54/54**	**36/36**	**17/18**
4137	Pictures as C-stimuli	**54/54**	**36/36**	**18/18**
4136	Pictures as C-stimuli	37/54	18/36	10/18
4132	Pictures as C-stimuli	23/54	22/36	9/18
4131	Acquired-function	**54/54**	**36/36**	**18/18**
4118	Acquired-function	**54/54**	**35/36**	**18/18**
4125	Acquired-function	**52/54**	**34/36**	**17/18**
4123	Acquired-function	**49/54**	**33/36**	16/18
4120	Acquired-function	48/54	27/36	12/18
4127	Acquired-function	30/30	17/36	11/18
4117	Acquired-function	29/54	19/36	9/18
4122	Acquired-function	24/54	22/36	10/18
4128	Acquired-function	20/54	12/36	6/18
4129	Acquired-function	16/54	13/36	6/18

Table 5. This table displays the test trials divided into two equal halves. It compares results on symmetry, 1-node, 2-nodes, 3-nodes and whether participant responds in accord with equivalence in each half. The criterion for responding in accord with equivalence is 0.9 (90%).

		First half					Second half				
Participant	Condition	SY	1N	2N	3N	EQ	SY	1N	2N	3N	EQ
4109	AA	17/18	15/27	12/18	4/9	0.67	17/18	18/27	9/18	5/9	0.68
4101	AA	15/18	15/27	10/18	2/9	0.58	17/18	11/27	9/18	6/9	0.6
4111	AA	16/18	8/27	4/18	3/9	0.43	13/18	11/27	5/18	1/9	0.42
4113	AA	15/18	15/27	10/18	3/9	0.60	13/18	15/27	6/18	2/9	0.5
4103	AA	13/18	10/27	11/18	4/9	0.53	15/18	7/27	16/18	2/9	0.56
4134	AA	14/18	6/27	11/18	4/9	0.49	14/18	9/27	9/18	3/9	0.49
4139	AA	12/18	14/27	8/18	4/9	0.53	6/12	11/27	10/18	2/9	0.4
4141	AA	15/18	11/27	4/18	2/9	0.44	15/18	14/27	5/18	3/9	0.51
4142	AA	18/18	16/27	6/18	3/9	0.60	14/18	18/27	9/18	5/9	0.64
4144	AA	14/18	3/27	4/18	4/9	0.35	13/18	5/27	5/18	4/9	0.38
4104	PC	18/18	27/27	18/18	9/9	1.00	18/18	27/27	18/18	9/9	1.00
4114	PC	18/18	27/27	18/18	9/9	1.00	18/18	27/27	18/18	9/9	1.00
4105	PC	17/18	27/27	17/18	7/9	0.94	18/18	27/27	18/18	9/9	1.00
4102	PC	18/18	22/27	16/18	6/9	0.86	18/18	26/27	18/18	9/9	**0.99**
4110	PC	18/18	23/27	15/18	5/9	0.84	18/18	26/27	18/18	9/9	**0.99**
4135	PC	17/18	27/27	18/18	9/9	0.99	18/18	27/27	18/18	8/9	0.99
4133	PC	18/18	27/27	18/18	8/9	0.99	18/18	27/27	18/18	9/9	1.00
4137	PC	18/18	27/27	18/18	9/9	1.00	18/18	27/27	18/18	9/9	1.00
4136	PC	13/18	19/27	12/18	4/9	0.67	13/18	18/27	6/18	6/9	0.60
4132	PC	14/18	13/27	11/18	5/9	0.60	10/18	10/27	11/18	4/9	0.49
4131	AF	17/18	27/27	18/18	9/9	0.99	18/18	27/27	18/18	9/9	1.00
4118	AF	18/18	27/27	17/18	9/9	0.99	18/18	27/27	18/18	9/9	1.00
4125	AF	18/18	25/27	16/18	8/9	0.93	18/18	27/27	18/18	9/9	1.00
4123	AF	18/18	22/27	15/18	7/9	0.86	18/18	27/27	18/18	9/9	**1.00**
4120	AF	17/18	23/27	13/18	4/9	0.79	18/18	25/27	14/18	8/9	**0.90**
4127	AF	14/18	12/27	8/18	5/9	0.54	16/18	18/27	9/18	6/9	0.68
4117	AF	15/18	14/27	10/18	5/9	0.61	15/18	15/27	9/18	4/9	0.56
4122	AF	13/18	11/27	10/18	7/9	0.57	13/18	13/27	12/18	3/9	0.57
4128	AF	14/18	10/27	5/18	4/9	0.46	8/18	10/27	7/18	2/9	0.33
4129	AF	15/18	9/27	7/18	4/9	0.49	11/18	7/27	6/18	2/9	0.36

Note: For the conditions, AA represents all abstract, PC is Pictures as C-stimuli, and AF represents Acquired-function as shown in previous tables.

Table 6. This table displays the pre-experimental and post experimental sorting of the stimuli set used in the experiment by all participants. Stimuli in the same experimentally defined class are marked with a common color. Red is for class 1 stimuli, Blue for class 2, and Green for class 3.

Participant	Pre-experimental sorting	Post experimental sorting
4109	A1-B1-C1. D1-C2-E2-E3. E1-B2-A3-B3. A2-D2-C3-D3.	A1-E1-C2-A3-C3. B1-C1-D1-E2-B3. A2-B2-D2-D3-E3.
4101	A1-C1. D1-C2-E3. A2-D2-B3-C3. B1-E1-B2. E2-D3. A3.	NOT AVAILABLE
4111	A1-B1-E1. C1-D1-A2-B2-C2-C3-D2-E2-A3-B3-D3-E3.	A1-B1-C1. C2-D2-E2. A2-B2. B3-C3-D3. D1-E1-A3-E3.
4113	A1-B1-C1-E1-B3-C3. A2-C2-D2-A3-D3-E3. D1-B2-E2.	A1-B1-C1-D1-E1. A2-B2-D2-E2-E3. C2-A3-B3-C3-D3.
4103	D1-E2-A3. C2-D3-E3. A2-D2-B3. B1-E1-B2. A1-C1-C3.	NOT AVAILABLE
4134	A1-B1-E1-B2-B3. C1-D1-E2-A3-C3. A2-C2-D2-D3-E3.	A1-B1-C1-D1-E1. A2-D2-A3-B3-C3. B2-C2-E2-D3-E3.
4139	C1-E1. B3-C3. A1-B1-B2. D1-E2--D3. A2-C2-D2-A3-E3.	A1-B1-E1-B2. C1-B3-C3. A2-D2. D1-C2-E2-A3-D3-E3.
4141	B1-A3-D3. A1-E1-B2. A2-D2-E3. C1-B3-C3. D1-C2-E2.	A1-B1-C1-D1-E1. B2-C2-C3-D3-E3. A2-D2-E2-A3-B3.
4142	A1-C1-B2-C3. E1-A2. B1-A3-B3. D1-E2. C2-D2-D3-E3.	A1-C1-B2-C3. E1-A2. B1-A3-B3. D1-E2. C2-D2-D3-E3.
4144	A1-C1-D1-C3. B1-B2-E2-B3. E1-D3. A2-C2-D2-A3-E3.	A1-B1-B2. C1-E1-E2-E3. D1-C2-A3-B3. A2-D2-C3-D3.
4104	B1-A2-A3-B3-C3. C1-E1-B2-D2-D3. A1-D1-C2-E2-E3.	A1-B1-C1-D1-E1. A2-B2-C2-D2-E2. A3-B3-C3-D3-E3.
4114	D1-E2-D3-E3. E1-B2-C2-A3. C1-A2-D2-B3. A1-B1-C3.	A1-B1-C1-D1-E1. A2-B2-C2-D2-E2. A3-B3-C3-D3-E3.
4105	A1-D1-C2-E2-E3. B1-C1-B2-D2-B3. E1-A2-A3-C3-D3.	A1-B1-C1-D1-E1. A2-B2-C2-D2-E2. A3-B3-C3-D3-E3.
4102	C1-C2-C3. A1-B1-E1-B2. D2-B3-E3. A2-A3-D3. D1-E2.	NOT AVAILABLE
4110	A1-B1-E1-B2-B3. C1-C2-C3. D1-E2-E3. D2-A3-D3. A2.	A1-B1-C1-D1-E1. A2-B2-C2-D2-E2. A3-B3-C3-D3-E3.
4135	D1-E2. D3-E3. C1-C2-C3. A1-B1-B2-B3. E1-D2-A2-A3.	A1-B1-C1-D1-E1. A2-B2-C2-D2-E2. A3-B3-C3-D3-E3.
4133	A1-B3. D1-E2. B1-B2. A3-E3. C1-C2-C3. D2. E1-A2-D3.	A1-B1-C1-D1-E1. A2-B2-C2-D2-E2. A3-B3-C3-D3-E3.
4137	A1-B2-C2-E2-D3. B1-C1-D2-B3-C3. D1-E1-A2-A3-E3.	A1-B1-C1-D1-E1. A2-B2-C2-D2-E2. A3-B3-C3-D3-E3.
4136	A1-B1-D1-E1-D3-E2-E3. C1-C2-C3. A2-B2-D2-A3-B3.	B2-B3-C3-D3-E3. A1-B1-C2-D2-E2. C1-D1-E1-A2-A3.
4132	A1-B1-B2-E2. C1-C2-C3. E1-A2-A3-B3. D1-D2-D3-E3.	C1-C2-C3. D1-E2-D2-E3. A1-B1-E1-B2. A2-A3-B3-D3.
4131	A1-B1-C1-E2. D1-E1--B2-A3-B3. A2-C2-D2-C3-D3-E3.	A1-B1-C1-D1-E1. A2-B2-C2-D2-E2. A3-B3-C3-D3-E3.
4118	A1-B1-C1-E1-B2-A3. D1-C2-E2-B3-D3-E3. A2-D2-C3.	A1-B1-C1-D1-E1. A2-B2-C2-D2-E2. A3-B3-C3-D3-E3.
4125	B1-A3-D3. A2-C2-E3. C1-D2-B3-C3. A1-D1-E1-B2-E2	A1-B1-C1-D1-E1. A2-B2-C2-D2-E2. A3-B3-C3-D3-E3.
4123	A1-B1-B2. A2-D2-B3. C2-A3-E3. D1-E2-D3. C1-E1-C3.	A1-B1-C1-D1-E1. A2-B2-C2-D2-E2. A3-B3-C3-D3-E3.
4120	C1-A2-D2-B3-C3. A1-B1-E1-B2. D1-C2-E2-A3-D3-E3.	A1-B1-C1-D1-E1. A2-B2-C2-D2-E2. A3-B3-C3-D3-E3.
4127	A1-E1-B2-C3. A2-C2-A3-E3. D1-E2-D3. B1-C1-D2-B3.	A1-B1-C1-E1. B2-C2-D2-E2. A2-D3-E3. D1-A3-B3-C3.
4117	A1-B1-E1. C1-A2-B2-D2-B3-C3-D3. D1-E2-C2-A3-E3.	A3-B3. A1-B1-C1-C2-C3. D1-A2-B2-E2-E3. E1-D2D3.
4122	D1-E2. C1-A2-B3-C3. A1-E1-B1-B2. C2-D2-A3-D3-E3.	C2-D2-E2. D3-E3. E1-A2-B2. A1-B1-C1-D1-A3-B3-C3.
4128	A1-E1-B1-B2. C1-D1-A2-C2-D2-E2-A3-B3-C3-D3-E3.	A1-B1-C1-E1-B2-A3-B3. D1-A2-C2-D2-E2-C3-D3-E3.
4129	A2-C2-D2-A3-D3-E3. D1-E1-E2-B3. A1-B1-C1-B2-C3.	A2-B2-A3-B3-C3-D3-E3. A1-B1-C1-D1-E1-C2-D2-E2.

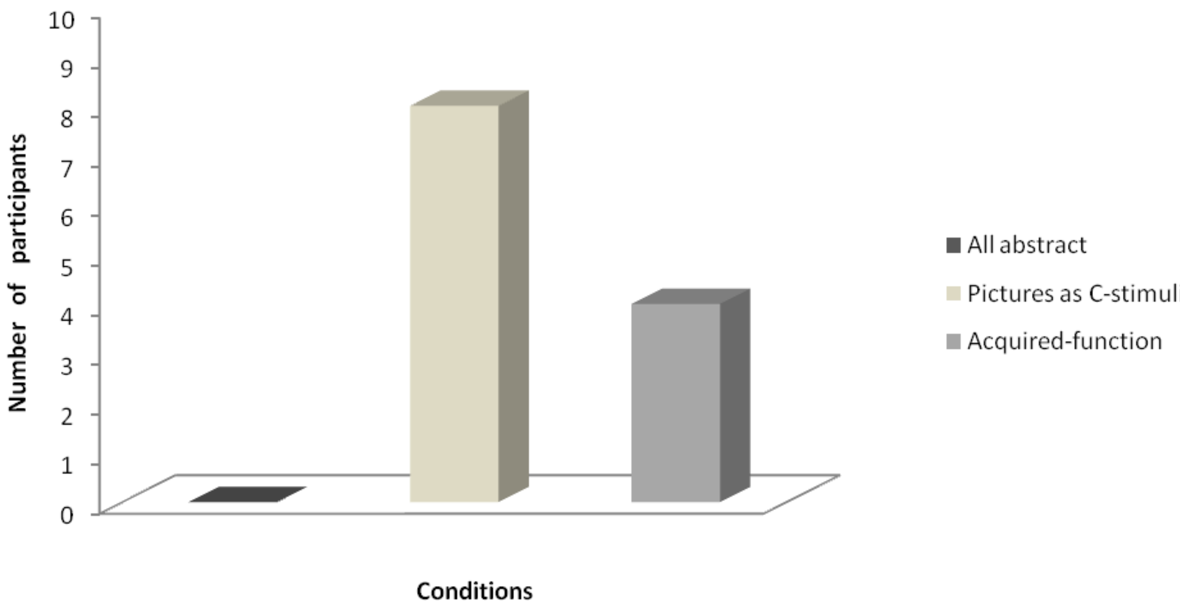
Figure 1

Stimuli set used in the experiment.

Figure 2.

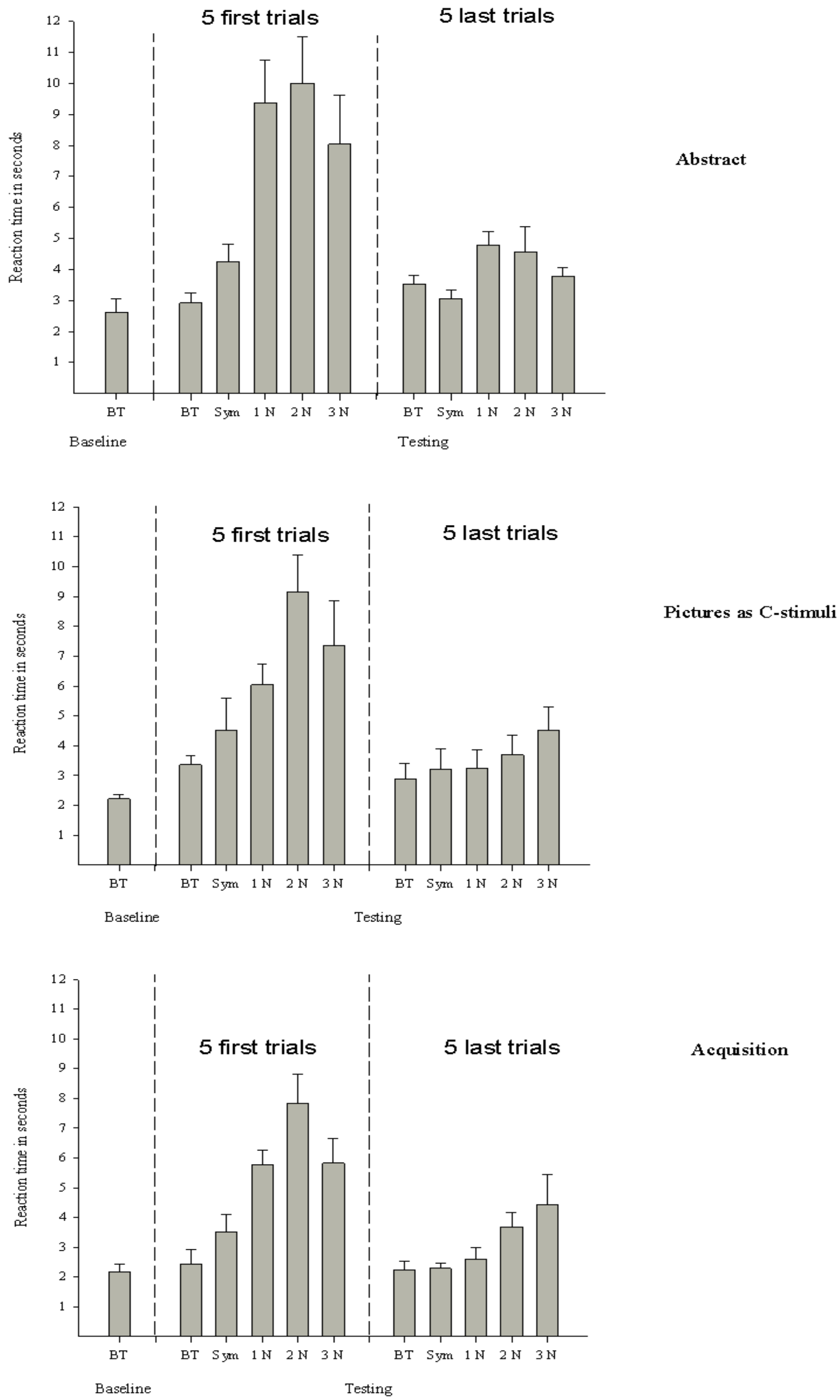
Stimuli set used for the discrimination training for participants in the acquired-function

Figure 3.



The figure shows the number of participants responding in accord with stimulus equivalence in the different conditions

Figure 4.



Reaction time in seconds for the last five training trials, the first five test trials and the last five test trials for participants in each condition.