THE EFFECTS OF DIFFERENTIAL TACT TRAINING OF STIMULUS COMPONENTS ON THE EMERGENCE OF ANALOGICAL REASONING

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Abstract

THE EFFECTS OF DIFFERENTIAL TACT TRAINING OF STIMULUS COMPONENTS ON THE EMERGENCE OF ANALOGICAL REASONING

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The purpose of the current study was to examine the effects of differential tact training in the emergence of analogical reasoning as measured by an equivalence-equivalence test. Six undergraduate students were initially trained to tact the images individually as “vek” and “zog”. Participants were then taught the relational tacts “same” and “different” for compound stimuli consisting of images from the same and different classes, respectively. Subsequently, participants were presented with tact and analogy tests consistent with symmetry (BA and CB) and transitivity (AC and CA). Lastly, participants were tested on the emergence of equivalence classes across individual stimuli. All six participants successfully completed the tact and analogy tests. Results showed that differential tact training of stimulus components was sufficient to establish two distinct separate classes.
Moreover, after learning to tact stimulus compounds with a common tact, participants passed all derived relational tests. These findings support the importance of tact training in facilitating the formation of both equivalence and equivalence-equivalence classes.

__________________________, Committee Chair
Caio F. Miguel, Ph.D.

__________________________
Date
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Chapter 1

INTRODUCTION

Analogy is defined as correspondence between the members of pairs or sets of linguistic forms that serves as a basis for the creation of another form (Merriam Webster, 2008.) In other words, an analogy is considered to be a process that involves identifying a common pattern of relationships between two relations to make a new analogous inference on a new concept or knowledge (Morsanyi & Holyoak, 2010). An analogy was originally used to denote proportionality and has been extended to the use of linguistic nature. Aristotle developed the classical analogical structure based on equality of proportion which includes four terms (A:B::C:D). The second term being related to the first as the fourth term being related to the third (Aristotle, trans. 1963, p. 110). To illustrate, consider the analogy bird:feathers::dog: _____ (hair). A language competent individual will be able to solve the fourth term after determining the relation between the first and second term (birds have feathers) and then applying the relation to the third and fourth term (Piaget, Montangero, & Billeter, 1977). The ability to solve an analogy is considered one of the most sophisticated skills in human responding and an important component in the development of cognitive performance, executive functions and higher order classes of behavior such as complex relational network, problem solving skills, creativity and understanding metaphors (Goswami, 1991, Sternberg & Downing, 1982).
Analogies and metaphors are often measured in academic performances (Sternberg, 1977b) and intelligence tests (Spearman, 1923). Analogical reasoning has been commonly observed in verbally competent individuals who are 12 years or older and has yet to be demonstrated with individuals who lack verbal competence and non-humans (Stewart, Barnes-Holmes & Roche, 2004; Carpentier, Smeets, and Barnes-Holmes, 2003; Carpentier, Smeets, Barnes-Holmes & Stewart, 2004). Even though cognitive psychologists have examined this phenomenon for decades, (Gentner, 1983; Goswami, 1991,1992; Gick & Holyoak, 1980; Vosniadou & Ortony, 1989; Singer-Freeman, 2005; Piaget, 2001) they have yet to successfully delineate the process by which analogical reasoning emerges and the procedures for developing or teaching it.

Over the years, cognitive psychologists have developed three accounts to explain analogical reasoning. The first account defined as ‘structural view’ (Vosnaidu, 1995) categorizes cognitive development into stages as identified by Piaget. This account claims that young children possess lower-order analogical reasoning skills and that higher-order analogical reasoning only develops between 11-12 years of age. The second view, which is called ‘knowledge based’ (Brown & Kane, 1989), holds that age is not a factor in successful demonstration of analogical reasoning, but having the knowledge in the area of the specific relations in the analogies given (Goswami, 1992; Goswami & Brown, 1989; 1990; Thompson & Oden, 2000). This theory suggests that relational experience plays a key role in analogical reasoning and that individuals who lack the
relational experience or are unfamiliar with the given terms will not be able to successfully respond in accordance with relations between relations. For example, a 5 year-old child will not be able to solve the analogy electrons: nucleus::planets: ______ (sun) simply because the child has yet to be exposed to such scientific information at school or at home. The third account named, ‘early competence with developmental change’ (Goswami, 1991) assert that changes in ability to solve an analogy take place with age. However, this change depends on one’s exposure to the specific analogy.

In examining these perspectives as a whole, the cognitive account continues to conceptualize analogical reasoning as an internal process in which the acquisition and development of knowledge is within the mind. The mind is claimed to be the central process that is responsible for the interaction between the physical and social environment and for the transferring of information from one system to another (Vosniadu, 1995). One of the reasons stated by Vosnai (1991) was that “without a clearer definition of what is meant by ‘knowledge’ or the ‘conceptual system’, the developmental import of this view is difficult to assess.” (p. 18) Therefore, limited success was achieved in delineating the process and in defining analogical reasoning over the years.

**Equivalence-Equivalence Model**

From the behavior analytic perspective, Skinner (1957) discussed an analogy as a process of abstraction through an extended tact from two different environmental events.
An extended tact refers to a response that is evoked by a novel stimulus that resembles (in some, but not all properties) a stimulus previously reinforced with the same response. For example, when a speaker calls another person a mouse, the speaker is referring to the common physical properties of a mouse such as small physique, timidness and soft-spoken nature of the person. Based on Skinner’s account of verbal behavior, this provided a starting point in the analysis of analogical reasoning (Lipkens & Hayes, 2009).

However, it was not until recently that behavior analysts began investigating this phenomenon using the equivalence-equivalence model (Hayes et al., 1989, 1996; Hayes, Barnes-Holmes, & Roche, 2001; Hayes & Hayes, 1992; Sidman 1986; Stewart, Barnes Holmes, Hayes & Lipkens, 2001). This theoretical model suggests that analogies can be interpreted as equivalence-equivalence relations (Barnes et al., 1997). Equivalence-equivalence relations are based on relating similar relations to similar relations (equivalence-equivalence) and relating different relations to different relations (non equivalence-non equivalence). To illustrate an equivalence-equivalence relation, consider the example “beer is to wine as kickboxing is to yoga.” The first relation “beer is to wine” is equivalent as both beer and wine are drinks and the second relation “kickboxing is to yoga” is also equivalent as both kickboxing and yoga are fitness activities. Additionally, the relation between the two classes or relations is also equivalent; hence the term equivalence-equivalence relation. Conversely, consider the following example
of “beer is to kickboxing as to wine is to yoga.” The terms within these classes are non-equivalent; however, the two 2-member relations are equivalent as each class has in common the fact that they each contain two terms that are different from one another.

**Research on Equivalence-Equivalence**

The first empirical study of equivalence-equivalence relations was conducted by Barnes, Hegarty and Smeets (1997). In this study, eleven adults (21-35 years old) and two children (9 and 12 years old) were taught conditional discriminations using delayed matching-to-sample tasks (MTS) using 12 nonsense syllables (ZID, CUG, VEK, YIM, BEH, DAX, ROG, PAF, MAU, JOM, KIB, FUB) that were designated randomly as A1, B1, C1, A2, B2, C2, A3, B3, C3, A4, B4, and C4. The participants were trained to respond according to two separate equivalence relations of A-B and A-C (A1-B1, A2-B2, A3-B3, A4-B4, A1-C1, A2-C2, A3-C3, A4-C4) and two separate non-equivalence relations (B1-C2, B2-C1, B3-C4, B4-C3). The participants were initially trained on four equivalence relations (A-B, A-C) to evaluate the emergence of transitivity (B1-C1, B2-C2, B3-C3, and B4-C4) and symmetry (C1-B1, C2-B2, C3-B3, and C4-B4). Then the participants were tested for the equivalence-equivalence responding by presenting pairs of equivalent and non-equivalent relations of BC compounds. During this task, the sample pairs consisted of stimuli from the same equivalence relations (e.g., B1C1) or from two separate equivalence relations (e.g., B1C2). In the subsequent experiment, the order of the testing was reversed such that equivalence-equivalence testing was initially
given followed by equivalence testing. Results from these experiments showed that all the participants successfully demonstrated equivalence and equivalence-equivalence relations, as well as non-equivalence and non-equivalence relations; thus demonstrating two different types of analogies.

As a result of this study, a growing body of empirical research on analogies has been conducted using the equivalence-equivalence model with the same general procedures developed by Barnes et al. (Stewart, Barnes-Holmes, Roche, & Smeets, 2001, 2002; Carpentier, Smeets, & Barnes-Holmes, 2002, 2003; Carpentier, Smeets, Barnes-Holmes & Stewart, 2004; Lipkens & Hayes, 2009; Cullinan, Barnes, & Smeets, 1998, 2000; Barnes-Holmes, Regan, Barnes-Holmes, Commins, Walsh, Stewart, Smeets, Whelan & Symond, 2005). Behavioral studies on analogies dated from 1981 to 2008 showed that 72% of the empirical research involved typically developing adults (mainly college students), 18% typically developing children, 3% involved atypically developing adults (i.e., asperger) and 7% atypically developing children (i.e., autism spectrum disorder, asperger, attention deficit hyperactivity disorder, dyslexic; Dymond, May, Munnely, & Hoon, 2010). The overall results of these studies suggest that equivalence-equivalence responding is an extension of equivalence responding since studies have shown that children and adults are more likely to be successful in analogical performances when given sufficient opportunities to demonstrate the prerequisite performances of equivalence relations (Stewart & Barnes-Holmes, 2004; Carpentier et al,
Nevertheless even with the growing number of empirical research on analogies, this literature has mainly focused on responding in accordance to an analogy via selection-based responding in matching-to-sample procedures (Lipkens et al, 2009; Healy, Barnes-Holmes & Smeets, 2000). In general, the matching-to-sample procedure used to examine analogies consists of a sample and three comparisons. Participants were trained to make an observing response and make the correct selection from the comparisons on the screen (e.g. told “point to this.”) As such, previous studies on analogies have used testing and training sequences that solely rely on listener training and have disregarded speaker training. Thus, to date there is still no literature explaining the verbal processes involved in analogical reasoning using Skinner’s (1957) verbal behavior approach.

One exception is a recent unpublished thesis conducted by Dickman (2012) in which the author utilized speaker training in the form of differential relational tacts to establish emergent equivalence-equivalence relations. It was hypothesized that by teaching participants to tact the relation between two component stimuli (i.e., tact stimulus compounds) as either, “same” if the two components were members of the same class or, “different” if they were not members of the same class (i.e., members of different classes), that participants would be able to tact compounds when components were re-arranged in accordance with symmetry and transitivity, and match these compounds in a matching-to-sample analogy test based on their common names. Thus,
when given a sample compound tacted as “same” participants would select a comparison whose components were also related as, “same,” and when given a sample compound tacted as “different”, participants would select a comparison also related as, “different” as predicted by the categorization literature (Horne & Lowe, 1996; Lowe, Horne, Harris & Randle, 2002; Lowe, Horne & Randle, 2004).

In this study, six typically developing adults were initially trained to tact compound stimuli of AB and BC relations as “same” when the components of the compound stimuli were from the same class membership (e.g., A1B1) and “different” when the components of the compounds were from different class membership (e.g., A1B2; See Table 1). The participants were then tested on the AB/BC relations in the absence of programmed reinforcers. Following the AB/BC Tact Test, the participants were exposed to an AB/BC Analogy Test to determine whether they could make the correct selection of the compound stimuli based on the relation given in the sample compound stimuli. Responding in accordance to the equivalence relation would result in selecting another compound stimulus with same class membership (e.g. select B2C2) when given a sample from the same class membership (e.g., A1B1). Conversely, when given a sample with different class membership (e.g., A1B2), the correct response would be to select compound stimuli with different class membership (e.g., B1C2). The Analogy Test was designed to examine whether tact training could reliably result in derived equivalence-equivalence relations. In the following phase of this study,
participants were tested on tact and analogy relations consistent with symmetry in which positioning of the stimuli were reversed (BA/CB relations). Subsequently, the participants were presented with AC/CA Tact and Analogy Tests consistent with transitivity. The final phase consisted of relating components of compound stimuli individually to assess whether participants responded differentially to two separate response classes (A1B1C1 and A2B2C2). Participants’ failure to complete any of the Analogy Tests resulted in the first remedial training in which the participants were directly taught the AB and then BC relations via matching-to-sample (Component Relations Training) and then represented the task that they initially failed. When the participants failed to pass the AC/CA Analogy Test following the first remedial training, participants were then given the second remedial training in which they were directly trained to tact the AC/CA relations and represented with the task that they failed.
Table 1

*Compound Stimuli Assignments for “Same” and “Different” Responses for AB/BC, BA/CB and AC/CA Relations*

<table>
<thead>
<tr>
<th>Relations</th>
<th>“Same”</th>
<th>“Different”</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB/BC</td>
<td>A1B1</td>
<td>A2B2</td>
</tr>
<tr>
<td></td>
<td>B1C1</td>
<td>B2C2</td>
</tr>
<tr>
<td></td>
<td>A1B2</td>
<td>A2B1</td>
</tr>
<tr>
<td></td>
<td>B1C2</td>
<td>B2C1</td>
</tr>
<tr>
<td>BA/CB</td>
<td>B1A1</td>
<td>B1A2</td>
</tr>
<tr>
<td></td>
<td>B2A2</td>
<td>B2A1</td>
</tr>
<tr>
<td></td>
<td>C1B1</td>
<td>C1B2</td>
</tr>
<tr>
<td></td>
<td>C2B2</td>
<td>C2B1</td>
</tr>
<tr>
<td>AC/CA</td>
<td>A1C1</td>
<td>A1C2</td>
</tr>
<tr>
<td></td>
<td>A2C2</td>
<td>A2C1</td>
</tr>
<tr>
<td></td>
<td>C1A1</td>
<td>C1A2</td>
</tr>
<tr>
<td></td>
<td>C2A2</td>
<td>C2A1</td>
</tr>
</tbody>
</table>

All six participants from Dickman (2012) demonstrated AB/BC analogy responding following the AB/BC Tact Training. They also successfully demonstrated BA/CB Tact and Analogy consistent with symmetry. However, only one participant passed the AC/CA Tact and Analogy Test (transitivity), as well as the Component Relations Test without the need for any remedial training. Two of the participants passed the Component Relations Test even though they failed the AC/CA Tact and Analogy Test. They responded successfully in the matching-to-sample when the figures were presented separately but not when the figures were presented as compounds. This suggests that the components of the compound stimuli did not retain the discriminative control when recombined with other components. Nonetheless, these participants passed
the AC/CA Tact and Analogy Tests upon completion of remedial training (AB/BC Component Relations Training). Results from P6 presented a unique finding such that the participant failed to demonstrate equivalence with individual stimuli but successfully passed the AC/CA Analogy Test without passing the AC/CA Tact Test. Her failure seemed to have been due to faulty tact responses on the derived relations. She tacted the relation as, “different” when presented with compound stimuli consisting of same class membership and, “same” for compound stimuli consisting of different class membership. The faulty tact responses also resulted in failure to pass the Component Relations Test even after the remedial training.

One of the limitations of Dickman (2012) that could have accounted for the mixed results was the fact that participants were only trained to tact the images as compounds rather than tacting them individually. Teaching the participants to tact the images as compounds may have resulted in the development of restricted discriminative control. In other words, the compound stimuli functioned as a single stimulus, rather than two separate stimuli (Stromer & McIlvane, 1993) whose relation served to control the tact (i.e., relational tact). Thus, when the images were recombined to form a new compound stimulus, the participants were not able to respond in accordance to equivalent relations. This would explain why four participants failed to pass AC/CA tests that involved stimulus combinations that they never seen before during training.
The present study addressed this limitation by training the participants to tact the individual images with common names based on their class membership, and then by training them to tact the compound images based on stimulus relations (“same” and “different.”) It was hypothesized that teaching participants to tact the stimuli individually would establish discriminative control by the individual components (Stromer & Stromer, 1990). That is, teaching the participants to tact the individual stimuli would establish individual discriminative control over the participants’ vocal responses (“vek” and “zog.”) Subsequently, the AB/BC Relational Tact Training would establish discriminative control by the relationship between each of the stimulus in the compound whose individual names participants could already emit. For instance, when given the compound stimuli A1B2, participants were trained to say, “different” since the two individual images each evoked a different tact. Conversely, with compound stimuli A2B2, participants were trained to say, “same” since each stimulus evoked the same individual tact.

According to the naming account (Horne & Lowe, 1996), upon training participants to tact each stimulus individually, as well as their relations, participants should be able to demonstrate emergent relational responding (e.g., Lowe, Horne, Harris, & Randle, 2002). That is, upon emitting a vocal response (e.g., “vek”) in response to an individual component stimulus (A1), the auditory response product should evoke the selection of the correct comparison (B1) establishing an equivalence class among
stimulus components (A1B1C1 or A2B2C2). The same process is applicable for compound stimuli in which a sample compound stimuli (e.g., B1A1) would control the relational tact “same” whose response product would evoke the selection of the comparison (e.g., C1B1, C2B2, B2A2) that depicts the same relation (i.e., “same.”)
Participants and Setting

Six typically developing adults between the ages of 21 and 31 participated in the study. Table 2 summarizes the participants’ age at the start of the study, gender, number of years in college and their major as well as their GPA. The participants were recruited from undergraduate classes in the Department of Psychology at California State University, Sacramento. Participants were selected under the condition that English was their first language and that they had no prior exposure to stimulus control research.

Sessions were conducted in the Verbal Behavior research laboratory at the California State University, Sacramento campus. The room measured 7m x 3m and included one meeting table, nine chairs, three cabinets, and three computer stations. Sessions were conducted two times per week with each session lasting no more than two hours in one of the computer stations. A 5 min break was given to the participants to prevent testing exhaustion each time 30 minutes elapsed. In this study, a computer based program (Elias & Goyos, 2010) was utilized. Participants were seated in front of a computer screen with a clear view of the computer and allowed access to the mouse during testing conditions. The experimenter was seated next to the participants to avoid cueing. All sessions were videotaped for data collection purposes.
Table 2

Demographic Information Across All Six Participants

<table>
<thead>
<tr>
<th>Task</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>P6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>24</td>
<td>31</td>
<td>21</td>
<td>23</td>
<td>23</td>
<td>25</td>
</tr>
<tr>
<td>Gender</td>
<td>Female</td>
<td>Female</td>
<td>Female</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Degree</td>
<td>A.A</td>
<td>A.A</td>
<td>B. A</td>
<td>A.S</td>
<td>A.A</td>
<td>A.A</td>
</tr>
<tr>
<td>Area</td>
<td>Liberal Arts and Music Concentration</td>
<td>Psychology with Sociology minor</td>
<td>Psychology</td>
<td>Social Science and Behavioral Learning</td>
<td>Psychology</td>
<td>Liberal Studies</td>
</tr>
<tr>
<td>GPA</td>
<td>2.8</td>
<td>2.3</td>
<td>3.0</td>
<td>3.2</td>
<td>2.96</td>
<td>2.8</td>
</tr>
</tbody>
</table>

**Materials**

The materials consisted of six familiar pictures in the Pre-Training condition and six unfamiliar pictures for all other conditions as used in Dickman (2012). The familiar pictures consisted of three fruits (orange, apple and banana) and three animals (elephant, cat and pig), while six black and white unfamiliar shapes were used as the training stimuli. Both familiar and unfamiliar shaped stimuli were coded (A1, B1, C1, A2, B2, and C2) for the experimenter’s use only. The letters (A, B and C) referred to the stimuli within the classes and the numbers (1 and 2) to the classes themselves (See Figure 1). All trial blocks in this study were pre-randomized by interspersing the stimuli to ensure that the stimuli from each class were not presented on three consecutive trials. Additionally, correct responses were equally distributed on the right and left side of the computer screen to control for location bias.
Dependent Measures and Experimental Design

The experimental design consisted of a non-concurrent multiple-baseline across participants (Watson & Workman, 1981). Each participant’s sessions were scheduled no more than one week apart to ensure participants were maintaining previously established performances. Participants were exposed to the following conditions: Pre-Training, AC/CA Pre-Test, A/B/C Component Tact Training and Test, AB/BC Relational Tact Training and Test, AB/BC Analogy Test, BA/CB Tact Test and Analogy Test, AC/CA Tact Post-Test, AC/CA Analogy Test and Component Relations Test (see Table 3).
Table 3

Sequence of Training and Testing

<table>
<thead>
<tr>
<th>Task</th>
<th>Stimuli Presented</th>
<th>Relations Trained</th>
<th>Relations Derived</th>
<th>Passing Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC/CA Tact Pre-Test</td>
<td>AC and CA compounds</td>
<td></td>
<td></td>
<td>15/16 correct within one trial block</td>
</tr>
<tr>
<td>A/B/C Component Tact Training</td>
<td>A, B, and C figures</td>
<td>A1-B1-C1 and A2-B2-C2</td>
<td></td>
<td>12/12 correct within one trial block</td>
</tr>
<tr>
<td>A/B/C Component Tact Testing</td>
<td>A, B, and C figures</td>
<td></td>
<td></td>
<td>12/12 correct within one trial block</td>
</tr>
<tr>
<td>AB/BC Tact Test</td>
<td>AB and BC compounds</td>
<td>A1B1, A1B2, A2B1, A2B2, B1C1, B1C2, B2C1, B2C2</td>
<td></td>
<td>16/16 correct within one trial block</td>
</tr>
<tr>
<td>AB/BC Analogy Test</td>
<td>AB and BC compounds</td>
<td>A1B1, A1B2, A2B1, A2B2, B1C1, B1C2, B2C1, B2C2</td>
<td></td>
<td>15/16 correct within one trial block</td>
</tr>
<tr>
<td>BA/CB Tact Test</td>
<td>BA and CB compounds</td>
<td>B1A1,B1A2, B2A1, B2A2, C1B1, C1B2, C2B1, C2B2</td>
<td></td>
<td>15/16 correct within one trial block</td>
</tr>
<tr>
<td>BA/CB Analogy Test</td>
<td>BA and CB compounds</td>
<td>B1A1,B1A2, B2A1, B2A2, C1B1, C1B2, C2B1, C2B2</td>
<td></td>
<td>15/16 correct within one trial block</td>
</tr>
<tr>
<td>AC/CA Tact Post-Test</td>
<td>AC and CA</td>
<td></td>
<td></td>
<td>15/16 correct within one trial block</td>
</tr>
<tr>
<td>Test</td>
<td>Compounds</td>
<td>Correct within one trial block</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>----------------------------------</td>
<td>--------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC/CA Analogy Test</td>
<td>AC and CA compounds</td>
<td></td>
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<tr>
<td>Component Relations Test</td>
<td>A, B, and C figures</td>
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<tr>
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<td>correct</td>
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<tr>
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<td>15/16 correct within one trial block</td>
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<td></td>
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Dependent measures included the percentage of correct tacts in the presence of individual and compound stimuli, the percentage of correct selection of compound and component comparisons in the presence of compound and component samples, respectively. Other dependent variables include the number of trials to achieve mastery across all training conditions, as well as participants’ vocalizations throughout the experiment.

Data was hand collected during all tact training and testing conditions while the computer program recorded all selection-based responses in the Analogy and Component
Relations Test conditions. Data were also collected for any vocal responses made by the participants throughout the experiment and at the end of the study when the participants

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
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<tbody>
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<td><img src="image3.png" alt="Image" /></td>
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<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
</tbody>
</table>

*Figure 2. Experimental Stimuli. Unfamiliar images used following AC/CA Tact Pre-Test condition.*

**Interobserver Agreement (IOA)**

A second observer was present to collect IOA and treatment integrity (TI) data during sessions. The experimenter was seated to the right of the participants and a second observer was seated to the left side of the participants while facing the computer. IOA was calculated using point-by-point agreement ratio whereby the number of agreements for each trial was divided by the total number of agreements and disagreements then multiplied by 100. The IOA across tasks averaged 99.8% (range from 92-100%) for P1, 98.7% (range from 87.5-100%) for P2, 99.0% (range from 90-100%) for P3, 99.5%
(range from 91.6-100%) for P4, 99.2% (range from 87.5-100%) for P5, and 99.7% (range from 95-100%) for P6.

**Treatment Integrity (TI)**

Treatment integrity (TI) was collected for 72.8% of the trial blocks except on the automated tasks (Component Relation and Analogy Tests). A trial was scored as “correct” when the experimenter delivered the vocal prompt at the correct prompt delay, praised for all correct responses including implementing differential reinforcement following the first correct response or implementing error correction following an incorrect response. A trial was scored as “incorrect” when the experimenter delivered the vocal prompt before or after the designated prompt delay for the trial block, failed to praise any correct responses, continued to provide reinforcement for prompted responses following the first correct response or failed to implement error correction following an incorrect response. Treatment integrity was calculated by dividing the number of correct trials by the total number of trials and then multiplying it by 100. The TI across tasks averaged 97.7% (range from 80.5-100%) for P1, 98.9% (range from 97.9-100%) for P2, 98.8% (range from 95.8-100%) for P3, 99.6% (range from 97.9-100%) for P4, 97.1% (range from 94.4-100%) for P5, and 100% for P6.
Procedures

Pre-Training

Pre-Training was designed to familiarize the participants with the computer-based instructions. The participants were presented with XY and YZ compounds consisting of six members from two classes (three members of “fruits” and three members of “animals”) to teach the participants to tact “same” and “different” (See Figure 1). A progressive prompt delay (Touchette, 1971) and differential reinforcement schedule (Karsten & Carr, 2009) were utilized. In Pre-Training, participants were trained on the baseline (XY/YZ) relations followed by Tact and Analogy Tests for all other relations (YX/ZY and XZ/XZ). During Tact Training and Testing conditions, participants were trained and tested to respond with “same” or “different.” A correct response was defined as saying, “same” when shown stimuli that were deemed members of the same class (e.g., X1Y1, Y1Z1, X2Y2, Y2Z2) and “different” when shown members of different classes (e.g., X1Y2, Y2Z1, X2Y1, Y1Z2). Praise (e.g., Saying, “nice work”) was delivered contingent on a correct response during training conditions. An incorrect response was defined as responding with, “same” when shown members of different classes (e.g., X1Y2) and, “different” when shown members of the same class (e.g., X1Y1), saying anything else or not responding. All incorrect responses resulted in an immediate implementation of the error correction procedure. Error correction consisted of the experimenter saying, “Wrong, not (same/different)” based on the sample stimulus shown.
on the screen. In Analogy and Component Relations Tests, participants were required to correctly select the comparison stimuli that corresponded to the sample stimuli. A correct response was defined as selecting a comparison compound stimulus of same numerical class for “same” and selecting a comparison compound stimulus of different numerical class for “different” based on the sample stimulus given (e.g., selecting X2Y2 instead of X1Y2 when given X1Y1). An incorrect response was defined as selecting the comparison compound stimuli of different numerical class for “same” and selecting the comparison compound stimuli of same numerical class for “different” based on the sample stimulus given. In Component Relations Test, participants were required to select the corresponding comparison stimuli based on the instruction given by the computer (i.e., “select same/different.”) A correct response was defined as selecting a comparison stimulus of same numerical class membership when instructed to, “select same” and selecting a comparison stimulus of different numerical class membership when instructed to, “select different” based on the sample stimulus given. An incorrect response was defined as selecting the comparison stimuli of different numerical class when given the instruction, “select same” and selecting the comparison stimuli of same numerical class membership when given the instruction, “select different.” Participants that met the passing criterion proceeded to AC/CA Tact Pre-Test, while participants that failed to meet the passing criterion after ten trial blocks were excluded from this study.
**AC/CA Tact Pre-Test**

The purpose of this condition was to ensure that the participants could not relate the arbitrary images prior to tact training. The experimenter read the following script to the participants:

“You will see a blue square on the screen, when you click on it another image will appear. You will say if the image is ‘same’ or ‘different’ but I will not tell you if you are right or wrong. Every now and then, you will see a common image from the previous task. Label those images by name. The harder you try, the faster this will go. Please summarize the instructions I just gave you.”

The participants were allowed to start the testing when they correctly summarized the instruction. One maintenance trial consisting of a compound of common images was presented on every fourth trial with a total of four maintenance trials in each block. Correct tact responses during maintenance trials were followed by praise. However, no reinforcement or feedback was delivered for correct or incorrect responses for the remainder of the trials. The first participant in each dyad proceeded to A/B/C Component Tact Training upon completion of one 20-trial block of AC/CA Tact Pre-Test while the second participant in each dyad was required to complete one additional block of AC/CA Tact Pre-Test (a total of two blocks of AC/CA Tact Pre-Tests) to ensure that repeated exposure to the Pre-Test did not result in improvement of their performance.
A/B/C Component Tact Training

The purpose of this training was to teach tacts of the individual unfamiliar shapes (components) as either “vek” or “zog”. Participants were taught to respond by saying, “zog” in the presence of each of the stimuli from class 1 (A1, B1 and C1), and to respond by saying, “vek” to each of the stimuli from class 2 (A2, B2 and C2). The experimenter read the following script to the participants:

“I am going to train you to label images as ‘vek’ and ‘zog’. You will see a blue square on the computer screen and when I click on the square another image will appear next to it. I will tell you to ‘say vek’ and you will repeat ‘vek’ and for some images, I will tell you to ‘say zog’ and you will repeat ‘zog’. I will praise you if you say it correctly. You are free to guess if an image is a ‘vek’ or a ‘zog’ as soon as it appears but soon I will not tell you what to say right away. I will correct you if your answer is wrong or if you do not respond and praise you if your answer is correct. The harder you try, the faster this will go. Please summarize the instructions.”

The training trials began once the participants correctly summarized the instruction with satisfactory accuracy. A progressive prompt delay was utilized during A/B/C Component Tact Training. Initially, a zero-second delay was used to teach the participants the name each of the unfamiliar images until the participants produced clear echoic approximations delivered by the experimenter for one 12-trial block. At the start of each trial, an
observing response was required which consisted of a blank blue square. Then the experimenter immediately said, “vek” or “zog” following the appearance of the stimuli on the computer screen and the participants were required to repeat the answer given. Praise was delivered for all correct prompted responses. However, following the first unprompted response only independent responses resulted in praise. The prompt delay was increased by one additional second when the participants responded prior to or following the prescribed prompt on 80% of the trials within one 12-trial block. However, if the participants began to respond correctly prior to the prompt, the experimenter skipped to the last prompt delay (4 s). An error correction procedure was implemented for all incorrect prompted or unprompted responses. The experimenter delivered the feedback of saying, “wrong, not zog/vek.” Upon correctly responding at 100% for one 12-trial block with programmed consequence, the participants progressed to A/B/C Component Tact Test.

**A/B/C Component Tact Test**

The purpose of this phase was to examine if the participants could accurately tact the unfamiliar images in the absence of programmed consequences. The participants were presented with blocks of trials similar to A/B/C Component Tact Training and required to tact the images as, “vek” or “zog.” The experimenter read the following instructions to the participants and made sure that they summarized the instructions with sufficient accuracy.
“You will see a blue square on the screen, when you click on it another image will appear. You will say if the image is a ‘vek’ or ‘zog’ but I will not tell you if you are right or wrong. The harder you try, the faster this will go. Please summarize the instruction.”

Once participants correctly summarized the instruction, they were allowed to manipulate the mouse to begin the test. Sessions were conducted the same way as in A/B/C Component Tact Training with the exception of no differential consequences or feedback provided for correct or incorrect responses. Participants were required to tact the images with 100% accuracy for one 12-trial block in the absence of programmed reinforcement. However, after every fourth trial, praise was delivered for attending to the task for 3s. If the participants failed to meet passing criterion, they were required to return to A/B/C Component Tact Training. This process was repeated until 100% accuracy was achieved for this condition.

**AB/BC Relational Tact Training**

In AB/BC Relational Tact Training, the participants were taught to tact the AB and BC compound stimuli as either, “same” or “different.” The stimuli consisted of pairs that have terms from the same class (e.g., A1B1, A2B2, B1C1, and B2C2) and pairs with terms from different classes (e.g., A1B2, A2B1, B1C2 and B2C1). When presented with a sample consisting of same terms (A1B1), a correct response was to say, “same” and when presented with a sample consisting of different terms (A1B2), a correct response
was to say, “different”. The experimenter read the following instructions to the participants and required summarization with sufficient accuracy.

“You will see a blue square on the screen, when I click on it another image will appear. I will tell you to, ‘say same’ or ‘say different’ based on the combination of images that will appear on the screen. You are free to guess at anytime, but soon I will not tell you what to say right away. I will correct you if your answer is wrong and praise you if your answer is correct. The harder you try, the faster this will go. Please summarize the instruction.”

Similar to A/B/C Component Tact Training, a progressive prompt delay was used. Prompted responses were initially reinforced; however, following the first unprompted response only independent responses resulted in praise. All incorrect responses resulted in the implementation of the error correction procedure in which the experimenter delivered the feedback of “wrong, not same/different.” Praise was withheld on all incorrect responses. Upon completing two blocks at 100% accuracy in the absence of prompts, participants proceeded to AB/BC Tact Test.

**AB/BC Tact Test**

The participants were tested for the accuracy of their tact (i.e., responding with “same” or “different”) when shown AB and BC relations that had previously been trained. The experimenter read the following instructions to the participants:
“You will see a blue square on the screen, when you click on it another image will appear. You will say if the image is ‘same’ or ‘different’ but I will not tell you if you are right or wrong. The harder you try, the faster this will go. Please repeat the instructions for me.”

Once participants repeated the instructions, they were allowed to begin the test. Sessions were conducted the same way as AB/BC Relational Tact Training with the exception that no differential consequences or feedback were provided for correct or incorrect responses. Familiar images consisting of XY and YZ relations were included as maintenance trials on every fourth test trial in a 16-trial block for a total of 20 trials. If the percentage of correct responses fell below 100% within a trial block participants were required to return to the AB/BC Relational Tact Training. This process was repeated until 100% accuracy was achieved on this test.

**AB/BC Analogy Test**

In this condition, the participants were tested on responding in accordance to equivalence-equality relations between AB and BC compounds. The experimenter read the following instructions to the participants:

“You will see a blue square in the corner of the screen. When you click on this square, an image will appear next to it. When you click on this image, two more images will appear below. Click on the one below that goes best with the one above. I will not tell you if you are right or wrong. From time to time, you will
see a familiar image from the previous task. You are to respond to those images like before. The harder you try, the faster this will go. Please repeat back these instructions to me.”

Following a standard matching-to-sample (MTS) procedure, the participants were shown a blue square on the upper left corner of the screen. They were then required to engage in an observing response by selecting the blue square on the screen to ensure that the participants were attending to the task. Once the participants clicked on the blue square, a compound sample stimulus appeared in the upper right corner of the computer screen. The compound consisted of pairs that have terms from the same class and pairs with terms from different classes (see Figure 2). When presented with a sample consisting of same terms (e.g., A1B1) a correct response was to select comparison stimuli whose terms belonged to the same class (e.g., B2C2). Alternatively, when presented with a sample consisting of different terms (A1B2), a correct response was determined to be selecting the comparison with different terms (e.g., B2C1). Praise and prompts were not delivered during test trials. Analogy maintenance trials (familiar images with XY and YZ relations) were presented following every fourth test trial in a 16-trial block for a total of 20 trials. The passing criterion was set at 94% accuracy (15 out of 16 trials) or higher within one 16-trial block in order for the participants to progress to the BA/CB Tact Test.
BA/CB Tact Test

The purpose of this condition was to test for the emergence of tact relations consistent with symmetry. Participants were given the same instructions as in the AB/BC Tact Test prior to the start of the test trials and the experimenter followed the same experimental procedure as in the previous Tact Test condition. Maintenance trials consisting of AB and BC compounds from AB/BC Relational Tact Training were presented following every fourth trial in a 16-trial block for a total of 20 trials. The inclusion of AB and BC compounds served to maintain participants’ responding and to maintain consistent reinforcement rates across all testing conditions. Passing criterion was set at 94% accuracy (15 out of 16 trials) or higher within one 16-trial block. However, participants were allowed to move to the next phase regardless of their performance.

BA/CB Analogy Test

Similar to the AB/BC Analogy Test, BA and CB stimuli whose terms from the same and different classes were tested for relations consistent with symmetry. Familiar images with YX and ZY relations were included as maintenance trials on every fourth trial in a 16-trial block for a total of 20 trials. No programmed consequences were implemented on test trials and praise was delivered for correct tacts on maintenance trials only. Passing criteria was set at 94% accuracy (15 out of 16 trials) or higher within one
16-trial block. However, participants were allowed to move to the next phase regardless of their performance.

**AC/CA Tact Post-Test**

The participants were tested on AC and CA relations similar to AC/CA Tact Pre-Test with maintenance trials consisting of AB and BC compounds from the AB/BC Relational Tact Training. Maintenance trials were presented following every fourth trial in a 16-trial block for a total of 20 trials. No programmed consequences were delivered for all test trials and praise was only given following correct responses on maintenance trials. Passing criterion was set at 94% accuracy (15 out of 16 trials) in order to proceed to AC/CA Analogy Test. Failure to correctly tact above 93% accuracy resulted in a second test trial. Failure on a second test block resulted in the participants completing the remedial training after completion of the remaining tests (see below).

**AC/CA Analogy Test**

Similar to AB/BC Analogy Test, the participants were tested on AC and CA relations consisting of terms from the same and different classes with AB and BC compounds from AB/BC Relational Tact Training serving as maintenance trials. Maintenance trials were presented following every fourth trial in a 16-trial block for a total of 20 trials. No programmed consequences were delivered for test trials and praise was only given following correct responses on maintenance trials. Participants were required to correctly tact 15 out of 16 trials (94% accuracy) in order to proceed to the
next condition. If participants failed to meet this passing criterion after three attempts, they were required to undergo remedial training (see below) and then repeat the AC/CA Analogy Test and the Component Relations Test.

**Component Relations Test**

Participants were tested for the emergence of relations among the individual components of the compounds (ABC). In this condition, participants were initially presented with a sample on the top left corner. The sample consisted of a component of the compound. The instruction, “select same” or “select different” which served as the contextual stimulus was delivered by the computer. Then a blank square appeared next to the sample and the participants were required to select the blank square as their observing response. Following the observing response, two comparison stimuli were presented at the bottom of the screen. Maintenance trials consisting of familiar images from the Component Relations Test in the Pre-Training was interspersed every fourth trial in a 16-trial block for a total of 20 trials. Similar to other test conditions, reinforcement was delivered on maintenance trials only. Passing criterion was set at 92% accuracy (22 of 24 trials) for one block for up to two blocks. Failure to meet the passing criterion after two attempts resulted in remedial training.

**Vocal Assessment**

At the completion of the Component Relations Test, the participants were asked specific questions related to their performance during the study to determine if they
utilized any specific strategy or developed any rules that may have aided with task completion. The three questions were, “What strategy did you use to match the shapes presented side-by-side?”; “What strategy did you use to match the single shapes?” and “Did you have any additional strategies to complete the tasks you’d like to share?” (Dickman, 2012).

**Remedial Training**

**A-B/B-C Component Relations Training**

Failure in any of the Analogy or the Component Relations Test resulted in directly training the participants the A-B and B-C relations. The participants were first shown an image (e.g., A1) and an observing response was required to ensure attending to the stimulus. Then they were presented with two comparison stimuli at the bottom of the screen (e.g., B1 and B2). The experimenter pointed to the sample stimuli (e.g., A1) and then to the corresponding comparison stimuli (e.g., B1) while saying “this goes with this.” The participants were required to select the comparison stimuli by clicking on the mouse following the prompt provided by the experimenter. Similar prompt delay, reinforcement and error correction procedures were utilized in this remedial training as used in AB/BC Tact Training. Passing criterion was set at 100% accuracy (16 out of 16 trials) for two consecutive blocks. Participants who successfully completed this remedial training were required to return to the condition that they initially failed; while
participants who failed to pass any of the Analogy Tests following this remedial training were required to complete the AC/CA Tact Training.

**AC/CA Tact Training**

If participants failed to pass any of the Analogy Tests following the remedial A-B/B-C Component Relations Training, they were then directly trained to tact AC and CA compounds. This condition was similar to AB/BC Relational Tact Training with the exception that AC and CA compounds were presented to the participants. Passing criterion was set at 100% accuracy (16 out of 16 trials) for two consecutive blocks.

Participants who successfully completed this remedial training were required to return to the condition that they initially failed, that is, either AC/CA Analogy Test or the Component Relations Test.
Chapter 3

RESULTS

Pre-Training with Familiar Images

Table 5 shows the number of trials to criterion and percentage of correct responses across training and testing conditions from each participant during Pre-Training with familiar images. P1 required a total of 64 trials to meet criterion on XY/YZ Tact Training. She scored 100% on all Tact and Analogy Tests including the Component Relations Test. P2 required 96 trials to meet criterion; she scored 100% on all Tact and AC/CA Analogy Tests but required three 16-trial blocks to meet the criteria of 94% accuracy for AB/BC Analogy Test ($M = 59.33\%$). In addition, she made one error on the BA/CB Analogy Test and Component Relations Test, which yielded 94% and 92% accuracy, respectively. P3 also required 96 trials to meet criterion. With the exception of the AB/BC Analogy Test condition ($M = 94\%$), she passed all the test conditions with 100% accuracy. P4 required only 48 trials to meet criterion. She scored 100% on all Tact Tests and Component Relations Test, but made one error on each the BA/CB and AC/CA Analogy Test ($M = 94\%$). P5 required 64 trials to meet criterion and scored 100% on the Tact, Analogy and Component Relations Tests. P6 required 48 trials to meet criterion for Tact Training. With the exception of the AC/CA Analogy Test condition ($M = 94\%$), she
passed all the test conditions with 100% accuracy. Overall, all six participants passed the XY/YZ Pre-Training within 48 to 96 trials.

Table 4

Results on Trials to Criterion for Pre-Training and Training Conditions Across Participants

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<thead>
<tr>
<th>Trials to Criteria</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>P6</th>
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<td>64</td>
<td>120</td>
<td>132</td>
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</table>

Unfamiliar Images

P1 and P2

Figure 3 shows percentage of correct responses across testing conditions for P1 (top panel) and P2 (bottom panel), while Table 5 shows the number of trials to criterion across training conditions for all participants. P1 performed at chance level (50%) during AC/CA Tact Pre-Test in one 16-trial block (see Fig. 3). She achieved mastery criterion for A/B/C Component Tact Training after 21 blocks (252 trials; see Table 5) and then passed A/B/C Component Tact Test ($M = 77.6\%$ across three 12-trial blocks). Following A/B/C Component Tact Test, she met criterion for AB/BC Relational Tact Training after
four blocks (64 trials). She also passed AB/BC Tact Test (100%) and AB/BC Analogy Test (100%), AC/CA Tact (100%) and AC/CA Analogy Test (94%) including Component Relations Test (100%) in one trial block per condition. However, during BA/CB Analogy Test, she required two 16-trial blocks ($M = 87.5\%$) to meet criterion.

P2 also failed the AC/CA Tact Pre-Test ($M = 25\%$ across two 16-trial blocks; see Fig. 3). This indicates that repeated exposure to the AC/CA Tact Pre-Test did not result in performance improvement. She met mastery criterion for A/B/C Component Tact Training within seven blocks (84 trials; see Table 5), but failed the A/B/C Component Tact Test (92%) on her first attempt. Following an additional two blocks of Tact Training (24 trials), she passed A/B/C Component Tact Test ($M = 96\%$ across two 12-trial blocks). She also passed both the AB/BC Tact and Analogy Tests within one 16-trial block (100% each). P2 also passed the Tact Tests for AB/BC relations and AC/CA relations (100% each) and Analogy Tests for BA/CB and AC/CA relations (94% each) within a 16-trial block per condition. Lastly, she passed the Component Relations Test with 92% accuracy in one 12-trial block.
Figure 3. P1’s and P2’s Performance Across Test Conditions. P1’s data is displayed on the top panel while P2’s data is on the bottom panel. Experimental relations are indicated by shape: circle for AC/CA, pentagon for A/B/C Component, square for AB/BC, triangle for BA/CB and triangle for Component Relations. Filled shapes represent analogy tests while open shapes represent tact tests.
**P3 and P4**

Figure 4 shows the percentage of correct responses across testing conditions for P3 (on the top panel) and P4 (on the bottom panel), while Table 5 shows the number of trials to criterion across training conditions for all participants. P3 failed the AC/CA Tact Pre-Test (44%) in one 16-trial block (see Fig. 4). She met criterion within 12 blocks (144 trials) for A/B/C Component Tact Training (see Table 5) and then proceeded to pass A/B/C Component Tact Test (100%) in one 12-trial block. During AB/BC Relational Tact Training, she required seven blocks (112 trials) to meet the mastery criterion. Thereafter, she passed with 100% accuracy within one trial block for the BA/CB and AC/CA Tact and Analogy Tests including the Component Relations Test.

P4 also failed the AC/CA Tact Pre-Test ($M=37.5\%$ across two 16-trial blocks; see Fig. 4). She required six blocks (72 trials) to achieve mastery criterion for A/B/C Component Tact Training (see Table 5) and then passed the A/B/C Component Tact Test (100%) in one 12-trial block. During AB/BC Relational Tact Training, she met criterion within four blocks (64 trials). Following that, she passed the BA/CB and AC/CA Tact and Analogy Tests with 100% accuracy in one 16-trial block each. Then she proceeded to pass the Component Relations Test with 100% accuracy in one 12-trial block.
Figure 4. P3’s and P4’s Performance Across Test Conditions. P3’s data is displayed on the top panel while P4’s data is on the bottom panel. Experimental relations are indicated by shape: circle for AC/CA, pentagon for A/B/C Component, square for AB/BC, triangle for BA/CB and triangle for Component Relations. Filled shapes represent analogy tests while open shapes represent tact tests.
**P5 and P6**

Figure 5 represents the percentage of correct responses across testing conditions for P5 (top panel) and P6 (bottom panel), while Table 5 shows the number of trials to criterion across training conditions for all participants. P5 performed at chance level (50% accuracy) during AC/CA Tact Pre-Test in a 16-trial block (see Fig. 5). He achieved mastery criterion for A/B/C Component Tact Training within ten blocks (120 trials; see Table 5) and then passed the A/B/C Component Tact Test (100%) in one 12-trial block. During AB/BC Relational Tact Training, he required four blocks (64 trials) to meet mastery criterion. Thereafter, he passed the AB/BC, BA/CB and AC/CA Tact and Analogy Tests with 100% accuracy in one 16-trial block for each condition. He also passed the BA/CB Analogy Test (94%) in one 16-trial block as well as the Component Relations Test (100%) in one 12-trial block.

P6 also failed the AC/CA Tact Pre-Test ($M = 43.5\%$ across two blocks; see Fig. 5). She met mastery criterion for A/B/C Component Tact Training within nine blocks (132 trials; see Table 5) and then proceeded to pass A/B/C Component Tact Test (100%) in one 12-trial block. During AB/BC Relational Tact Training, she required seven blocks (112 trials) to meet criterion. She passed AB/BC, BA/CB and AC/CA Tact and Analogy Test conditions with 100% accuracy within one block per condition. Moreover, she also met criterion for Component Relations Test (100%) in a 12-trial block.
Table 5 depicts trials to criterion across testing and training conditions for all six participants. There appears to be no correlations between the participants’ demographic information (i.e., GPA, age, gender, major and number of years in college) with the number of trials to achieve criterion in training and testing conditions.

![Graph showing performance across test conditions]

**Figure 5.** P5’s and P6’s Performance Across Test Conditions. P5’s data is displayed on the top panel while P6’s data is on the bottom panel. Experimental relations are indicated.
by shape: circle for AC/CA, pentagon for A/B/C Component, square for AB/BC, triangle for BA/CB and triangle for Component Relations. Filled shapes represent analogy tests while open shapes represent tact tests.

**Participants’ Vocalizations and Self-Reports**

The experimenter collected data on participants’ vocalizations throughout experimental conditions, as well as interviewed participants at the completion of the study to assess whether any specific verbal strategies were utilized.

P1 was the only participant who emitted vocalizations while completing the tasks (i.e., without any prompts). She tacted the samples during Analogy Tests in Pre-Training (XY/YZ relations, YX/ZY relations and XZ/ZX relations) and the AB/BC Analogy Test by saying “same” and “different.” For example, during the AB/BC Analogy Test, when shown a sample, P1 would say, “different” and then moved her cursor to the corresponding comparison and then said, “different” prior to making her selection. P1 asked the experimenter prior to starting the BA/CB Analogy Test if she needed to label each of the images prior to making her selection, after which she was told, “You can say whatever you want.” As for the other five participants, they did not emit any spontaneous vocalizations during testing conditions.

When asked if any strategy was used to learn or remember the images when shown individually during A/B/C Component Tact Training, P3 reported to have named all stimuli belonging to class 1 (Vek) as “non-shape” because “they were odd shapes.”
She also named all stimuli belonging to class 2 (“zog”) as “shapes” because, according to her, “they were common shapes.” Moreover, she also reported during the vocal assessment to provide an exception to this rule by tactual B2 as a “shape” and C1 as a “non-shape.”

P6 stated that she labeled each image individually and then tacted their relation. She said, “I labeled each of them individually and then figure out if I was saying “vek” for both of them; then it would be same.”

The rest of the participants reported to have memorized the images as “vek” and “zog” based on the tact training given by the experimenter. As such, these participants reported having labeled the stimuli (i.e., “vek” or “zog”) and then their corresponding relation (i.e., “same” or “different”) to solve Tact, Analogy, and Component Relations Tests.

When asked if any kind of visualization strategy was used to learn or remember the images when shown individually during A/B/C Component Tact Training, P1 reported visualizing the images in a way that “B1 fits into C1 and that’s how I figured it was the same.” P4 reported that B1 looked like “V” for vek. P5 stated during the interview that he would look for the corners or edges in the B1 and C1 stimuli to visualize a “V” shape in those images and remember them as “vek” since the word starts with the letter “V.” He reported to have made up a rule to exempt C2 as a “vek” since it was another shape that did have corners to resemble a “V” but is not in the same class
membership as B1 and C1. Moreover, he also reported to “associate” the images in the “zog” category as buttons on a DVD controller (i.e., “I remember the triangle when compared to the plus sign as DVD symbols for play and increase or decrease the volume.”) P6 reported to use visualization strategies for two of the vek images - B1 and C1 (e.g., “For vek, I related them to vectors because it has points.”)

During the vocal assessment, all participants reported to have used a form of verbal mediation in determining the relations between the components in the compound. P1 reported, “I had to go to each one and say which one was which one. If they were both ‘vek,’ I would say ‘same’ or if they were both ‘zog,’ I would say ‘same.’” P2 stated that she would tact each of the images in the compound to determine the relational tact (e.g., “vek zog; different.”) P3, P4 and P5 also reported to attend to each of the images and then determine the relational tact (e.g., “I would look at one first. I would always look at the picture in that corner and see what that one says, either vek or zog. Then look at the other picture. If it was not a rectangle compared to that picture, then I would say whatever it was,” “I would look at each one and tell myself whether it was vek or zog. And if they were both vek then they are the same,” “I would look at this one and knew that it was a vek and this one as a ‘V’ and that how I knew they were linked together.”) P6 stated, “I just labeled them individually and then figure out whether I was saying vek for both of them. Then obviously they are the same.”
Chapter 4

DISCUSSION

The purpose of the current study was to examine the effects of differential tact training of stimulus components, as well as relational tact training of stimulus compounds on the emergence of analogical reasoning (i.e., equivalence-equivalence relations). All six participants were initially trained to tact the images individually (i.e., “vek” and “zog”) and then tact their relations when presented together (i.e., “same” and “different.”) Then participants were presented with Tact and Analogy Tests consistent with symmetry, transitivity, and equivalence. All six participants successfully passed the tact and analogy tests without requiring any remedial training. Results also showed that by teaching the participants to tact the stimuli individually, discriminative control of the individual components into two separate classes was established. As such, when they were presented with a new compound stimulus, they could not only tact the relation between components, but also match compounds based on the relations between their components (“same” or “different.”) These results further support the findings from previous equivalence-equivalence research whereby most adult participants successfully demonstrated emergence of equivalence-equivalence relations (Carpentier et al., 2002, 2003; Stewart et al., 2001, 2002 & Lipkins and Hayes, 2009). Moreover, this study extends the naming literature (Horne & Lowe, 1996) by suggesting common and
relational tact training led to the formation of equivalence, as well as equivalence-equivalence classes (Lowe, Horne, Harris, & Randle, 2002; Miguel, Petursdottir, Carr & Michael, 2008; Sprinkle & Miguel, 2012).

The results of the current study are a clear departure from those obtained by Dickman (2012) in which only one participant successfully demonstrated transitivity tacts and equivalence-equivalence without remedial training. Dickman hypothesized that the failure in the emergence of AC and CA relations could have been because AC/CA compounds had never been directly correlated with differential availability of reinforcement to function as discriminative stimuli for the response “same” and “different.” The compound stimuli functioned as a single discriminative stimulus as opposed to two separate discriminative stimuli to evoke the relational tact. Therefore, when the compound stimuli were recombined to form a new compound stimulus, they failed to produce the relational tact and make the correct corresponding selection in the analogy test.

The current study addressed the hypothesis of the pairing of AC and CA stimuli functioning as a conditional stimulus by incorporating differential tact training of the components to ensure that each separate stimulus exerted individual discriminative control prior to being recombined to form a new compound stimulus. During A/B/C Component Tact Training, participants were shown individual components of the compound and trained to tact either, “vek” for A1, B1 and C1 or “zog” for A2, B2, and
C2. By doing so, each stimulus would acquire an individual discriminative function when evoking either “vek” or “zog,” as well as a compound function, when evoking the relational tacts, “same” or “different.” Thus, when shown A1C1, for example A1 and C1 should each exert an equal amount of discriminative control for the tact “vek,” as well as occasion the relational tact “same.” However, when given A1C2, A1 should exert discriminative control for the tact “vek,” while C2 should exert discriminative control for the tact “zog”, and together they should occasion the relational tact “different.”

Moreover, one can also rule out the success in the emergence of BA and CB relations (symmetry) as a product of generic tact extension since all participants passed the AC/CA conditions. It is quite possible that because BA and CB compounds were physically similar to the trained compounds AB and BC (just reversed in the positioning of the components), that participants’ responding could have been due to simple stimulus generalization. However, during A/B/C Component Tact Training, a discriminative function was established for each component (“vek” or “zog”) as to guarantee attendance to individual stimuli. If this discriminative function were not established, participants could have still passed the symmetry tests, but would have failed AC/CA conditions since AC/CA do not closely resemble the originally trained compounds (AB/BC). Since this was not the case, we are led to believe that BA/CB tests served as true measures of symmetrical responding.
The results of this study can be interpreted in light of Horne and Lowe’s (1996) naming account. As mentioned above, during A/B/C Component Tact Training, participants were directly taught to tact within-class stimuli using a common topography (vek or zog). This differential tact training was sufficient to establish two distinct classes. When shown compounds, such as A1C2, participants may have been (covertly or overtly) tacting each of the images in the compound stimuli (“vek-zog”) which could evoke the response “different” or tacting the compound as “different.” Alternatively when shown a sample of A1C1 within the Analogy Test, the participants could have also emitted the intraverbal, “vek-vek is same” and then proceed to make the selection of other compounds that occasioned the same relational tact. This is consistent with P1’s vocalizations whereby she spontaneously tacted the sample and the corresponding comparison stimulus (as “same” or “different”). Moreover, verbal reports given by all participants suggested that they may have used some form of verbal strategy to solve the analogy test (e.g., P6 stated “I looked at each one and tell myself if they were vek or zog. If they were both vek, then they are same.”) It should be noted that P3 was the only participant to report the use a different tact for the images (i.e., covertly tacting the images as “shape” and “nonshape”) to determine the relation between the images. Nonetheless, she reported to use a similar verbal strategy (e.g. “I would look at the right corner picture and see what that one say; either a ‘shape’ or a ‘not a shape.’ Then I would look at the other one and say either same or different.”)
Stromer, Mackay and Remington’s (1996) analysis differs from Horne and Lowe’s naming account such that verbal behavior may serve solely to enhance discriminative control and does not play a definitive role in the formation of stimulus classes and equivalence. According to Stromer et al., the environment-behavior relation, such as the reinforcement contingency, is the one responsible for establishing stimulus control (also see Sidman, 2000). When comparing tact training to listener training, tact training may have an advantage over selection-based tasks. Tact training establishes discriminative control of topographically distinct behaviors while listener training establishes discriminative control for only one topography of behavior. Specifically, during tact training, reinforcement was delivered for saying “vek” or “zog” in the presence of the correct component or “same” or “different” in the presence of the correct compound stimuli. As for listener training, reinforcement was delivered for engaging in the same response of touching the screen or clicking on the mouse for a correct comparison. As such, it was expected for the participants to demonstrate the emergence of AC and CA relations even though these compounds were never directly trained because stimulus control has been established during tact training in order for equivalence-equivalence to take place. This differed from Dickman’s (2012) study such that the participants were never trained to respond to the images individually and therefore stimulus classes may have not been established for this reason.
Limitations

There are two notable limitations in the current study. First, the participants were not required to overtly tact each of the images and their relations for the compound stimuli during Tact and Analogy Tests. As such, the participants may have not utilized any verbal strategies or possibly used other meditational responses when solving the Tact and Analogy Tests. As reported by P3, she primarily utilized the tact “shape” and “non-shape” in determining the relations in a compound stimulus and would rely on this rule that she developed using intraverbal mediation (nonshape is zog) during Tact and Analogy Tests. Even though she successfully passed all the Tact and Analogy Tests, there is the possibility that she may have developed a faulty rule. If she were to develop a faulty rule, her data would indicate failure across all testing conditions and such error would only be identified at the end of the study when the experimenter conducted the interview, which was not the case. Moreover, there is the possibility that the participants’ verbal reports after the experiment were not in accordance with the strategies they used (if any) while performing the tasks (Stromer, Mackay & Remington, 1996).

Second, the current procedure focused on simple analogies with limited concepts (i.e., same and different). This study only used three terms whereas classical analogy tasks typically consist of four terms (a:b::c:d). Therefore, in order for this procedure to be of value in applied settings (e.g., to teach words or match concepts), the ‘d’ term needs to be included and be tested using different concepts.
Future Research

Future studies should attempt to address the limitation described above by requiring the participants to engage in overt vocal behavior. By doing so, any inaccurate self-regulated rules and verbal mediation strategies can be identified during the study to explain the participants’ failure to derive equivalence-equivalence relations. One suggestion is to use a protocol analysis by recording all vocalizations made by the participants during the study in attempt to assess if ongoing task performance is governed by any covert verbal rules and if overt vocalizations are functionally equivalent to the rules they developed (Hayes, White & Bissett, 1998). It is plausible that any changes in their self-regulated rules, verbal mediation and task performance could lead to a detection of inaccurate verbal mediation.

Additionally, future research should attempt to replicate the procedure of the current study without the AB/BC Relational Tact Training. It is possible that tact training of the individual stimuli (i.e., saying “vek” or “zog” for each of the stimuli) would suffice for them to derive the relational tact (i.e., “same” or “different”) during the Tact Test. For instance, in the presence of A1B1, they should say, “vek-vek,” which the response product should evoke saying “same.” Thus, during the Analogy Tests, the stimulation produced by the naming response (saying, “vek-vek”) would serve as a controlling stimulus for the selection of a comparison that also includes “same” components. If
participants can derive the relational tact without direct training, this would yield a more efficient technology for teaching analogies.

Lastly, future studies should use response latencies during testing as an additional dependent measure to obtain additional evidence that verbal mediation may have been used to solve analogies. This is because longer latencies from the onset of the sample to the selection of a comparison may suggest that participants were engaging in covert behavior. However, research shows that response latencies may decrease overtime (Tomanari, Sidman, Rubio & Dube, 2006). This could be because previously seen stimuli readily function as a discriminative stimulus to produce the relational tact and selection response. Hence, even though long latencies may strengthen the verbal mediation account, they will not serve as unequivocal evidence.

**Implications**

One major implication in this study is that correct tacts seemed to be correlated with performance on Analogy Tests. This suggests that naming may play a role in the emergence of equivalence-equivalence relations. According to Horne and Lowe (1996), naming is a higher order class of behavior that involves a bidirectional relation between a class of objects and events and the speaker-listener behavior they occasion. Every single member of a class needs to evoke the same name in order to become part of an equivalence class. For instance, in the presence of A1, the tact “vek” is evoked, whose product evokes the selection of another “vek” such as, B1. Additionally, when presented
with a sample compound such as B1A2 a relational tact is evoked (e.g., “different”), whose response product evokes the selection of another “different” compound such as C2B1. This interpretation relies on the fact that tact training of components and compounds also led to the emergence of selection responses (listener behavior), without which correct categorizations or matching would have not occurred (e.g., Miguel, Petursdottir, Carr, Michael, 2008). To further support the naming analysis, future studies should attempt to assess whether the presence of listener behavior is correlated with positive analogy test results. In other words, if participants can tact the compounds as “same” but not select them when given the auditory stimulus “same,” then they should not be able to pass analogy tests, since their own tacts would not serve as discriminative stimuli for the selection of the correct comparison (Miguel & Petursdottir, 2009).

Moreover, it should be noted that tact training may not only be efficacious in demonstrating emergence of equivalence-equivalence relations but also appears to be more economical. In the current study, tact training yielded a mean of 93 trials (range: 64-132 trials) while in the Carpentier et al., participants required an average of 207 trials (range: 168-279) of matching-to-sample training to demonstrate equivalence-equivalence performances. Additionally, in the current study, all six participants passed analogy tests which are not necessarily the case in other studies using matching-to-sample procedures (Carpentier et al., 2002; Lipken et al. 2009). Future studies should compare the current
procedure with the traditional listener training (Barnes et al., 1997; Carpentier et al., 2002) as an attempt to establish analogical reasoning in children and adults.

With that said, this study is one of the first series of analogy studies to produce three-member equivalence classes using simple discrimination (i.e., tact training) of compounds. By directly training the relational tact, we obtained the same emergent relations that were obtained in the previous studies that used either a go/no-go procedure or selection-based conditional discriminations (Debert, Matos, & McIlvane, 2007; Debert, Hunziwara, Faggiani, De Mathis, & McIlvane, 2009; Stewart et al., 2001, 2002; Carpentier et al., 2002, 2003, 2004; Lipkens & Hayes, 2009; Cullinan et al., 1998, 2000).

Since solving analogies is considered an important cognitive skill commonly assessed during standardized testing (e.g., SAT and GRE), the current findings have great implications for the continued development of efficient strategies for teaching adults and children to form and solve analogies. The findings from this study suggest that clinicians may produce successful emergent equivalence-equivalence performance in a more time efficient manner by using tact training alone. However, future studies should compare these strategies with the ones that primarily rely on matching-to-sample training (Stewart, Barnes-Holmes & Weil, 2009).
Appendix A

A/B/C Component Tact Training

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<tr>
<td>Prompt Delay: 0s</td>
<td>Reinforcement: CRF until unprompted + response occurs, then differential</td>
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<th>Response (P. +, ec)</th>
<th>Treatment Integrity (+/-)</th>
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% Correct Responses (+/12):  
% Prompted Responses (P/12):  
Notes:
Appendix B

AB/BC Analogy Test

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<th>Tact Sample</th>
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% Correct Responses (+/16):

% Correct Maint (+/4):

% (+/20):
Appendix C

Component Relations Test

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% Correct Responses (+/12): % (+/15):
% Correct Maint (+/3):
REFERENCES


