University of Nevada, Reno

Examining the Effects of Using Correlation and Yes/No Evaluative Procedures on Establishing Derived Stimulus Relations

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Psychology

by

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May, 2018

THE GRADUATE SCHOOL

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prepared under our supervision by

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Entitled

Examining The Effects Of Using Correlation And Yes/No Evaluative Procedures On Establishing Derived Stimulus Relations

be accepted in partial fulfillment of the
requirements for the degree of

DOCTOR OF PHILOSOPHY

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Abstract

The purpose of this series of studies was to evaluate the extent to which a non-reinforcement based correlation training procedure could combine with a Yes/No evaluation method to establish and test for derived equivalent and spatial relations. In the first experiment, participants were trained stimulus pairs between A-B and B-C across three stimulus sets. Participants were subsequently tested using a Yes/No evaluative procedure of untrained B-A, C-B, A-C, and C-A relations. Experiment two utilized the same training structure as well as testing for the same derived relations, however used a complex semi-random trial structure. In both experiments 1 and 2 the majority of participants responded accurately to all of the possible tested derived relations. In experiment 3, the same training and testing procedure was employed to establish spatial relations. Tests for possible derived spatial relations were observed for the majority of participants. The three experiments demonstrated the effectiveness of a correlation training and Yes/No evaluation procedure that to date has not been reported in the derived relational responding literature.

Keywords: Stimulus equivalence, derived relational responding, match to sample, Yes/No evaluation, correlation training.

Acknowledgements

To my wife, you took a stand for me, and that moves me beyond measure. Thank you. I love you. To Linda, I reverently hold dear the time I get with you and for the graciousness with which you have mentored me. To Lab, I was never so nervous as I had been preparing to share work with you, and am made better for having done so. I am honored to be a part of an enduring legacy of natural scientists, all of whom I admire and thank for their contributions. And lastly to my son, much of what this work represents was done before you, and only now that you are here does it makes any sense. Thank you. I love you.

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Introduction

Derived stimulus relations have been an active area of experimental and conceptual behavior analysis for much of the last 45 years. Sidman (1971) illustrated the efficacy of using a conditional discrimination procedure to demonstrate reflexive, symmetrical, and transitive relations required for equivalence to be considered present among three or more stimuli. In this initial demonstration, Sidman was able to teach relations between words spoken to the participant and their corresponding textual counterparts, as well as pictures of these stimuli and saying their names. For example, hearing the word "cat" and selecting the text 'Cat' as well as seeing a picture of a cat and saying the word 'Cat'. Through this training the participant was then able to match pictures and their printed names and vice versa. The important product of such training is that, in the absence of direct training, a form of reading comprehension was observed between printed words, pictures, and names. It is this derived performance that has led to the idea that equivalence (Sidman, 1992; 2009), or derived relational responding more generally, is the basis for human language (Hayes & Hayes, 1989; Hayes, Barnes-Holmes, & Roche 2001).

Studying equivalence has largely been done using some variation of the same match-to-sample (MTS) procedure that Sidman used in the initial study (Barnes-Holmes, et al. 2004; Sidman, 2009). MTS is a procedure whereby conditional discriminations are arranged such that a participant, when shown as stimulus (the sample) and then given the opportunity to select among comparisons may produce reinforcement if his or her selection is correct according to pre-determined arbitrary relations. As Sidman (2009) points out, "the involvement of arbitrary matching brings up what many consider to be the most interesting aspect of equivalence relations" whereby "subjects come to match stimuli that share no physical properties and that have never been paired with or directly related to each other" (p. 5).

The prototypical MTS training arrangement is one where a sample stimulus is presented and two or more comparison stimuli follow, after which the participant selects one comparison and receives feedback. Perhaps what has made the MTS procedure so valuable to investigators has been its versatility. MTS can be the context under which both the training of specific relations among stimuli and the testing for untrained relations among them is configured. Further, the basic parameters of the MTS procedure are such that parametric research programs are easily established. For example, various training structures have been used where by training relations are situated in linear series vs. nodal structures (Green & Saunders, 1998). The use of the MTS procedure is not without criticism, however.

Barnes-Holmes, Barnes-Holmes, Smeets, Cullinan, and Leader (2004) suggested that the reliance on the MTS as the dominant procedure to establish and test for equivalence sets this research area apart from other behavior analytic areas of investigation (e.g. reinforcement, discrimination/generalization, extinction, etc.) for which various methods under numerous conditions have been used to investigate other characteristics of environment-behavior relations. Fields, Reeve, Varelas, Rosen, and Belanich (1997) have also raised concern that the primary means for investigating equivalence being limited to MTS or variants thereof has limited the practical and theoretical scope of equivalence. Although MTS remains the preferred experimental procedure for studying equivalence (Minster, et al. 2011) there have been attempts to broaden the methods of training and testing for relations among arbitrary stimuli.

Alternatives Training Approaches

Leader, Barnes, and Smeets (1996) attempted what they termed a respondent-like training procedure where a participant was exposed to six stimulus pairs made up of nonsense syllables (e.g. DAX or ROG) for 60 trials. A trial consisted of one stimulus (A1) followed by another stimulus (B1) after a .5 second delay (i.e. within pair delay). After B1 was presented a new trial would begin after a three second delay (i.e. between pair delay). This procedure was initially thought of as “respondent like” due to the explicit pairing or correlation between two stimuli – much like a neutral stimulus (NS) would be correlated with a unconditioned stimulus (US) repeatedly such that the NS would become a conditioned stimulus (CS) in the sense that the organism would respond to it as if it were the US. A further likeness with respondent arrangements is the absence of an operant response resulting in environmental change (i.e. reinforcement). In other words, the Leader, et al. (1996) procedure represented the first[1] attempt to train relations among stimuli where there was no overt response requirement and thereby no subsequent feedback and/or operant reinforcement. In their study the participant was told to watch pairs of stimuli on a computer screen and were later evaluated for accurate symmetrical and equivalence responding in a MTS format. This initial report demonstrated the plausibility of a correlation-based procedure with the authors reporting that 84% of the participants successfully demonstrated accurate responding to tests of symmetry and

[1] Arguably this is not the ‘first’ as this procedure shares similarities with the paired – associative traditions (Sidman, 1994).

equivalence (p. 700). This success rate was comparable to results reported by Wulfert, Dougher, and Greenway (1991) where 83% of their participants successfully responded in accordance with equivalence relations using MTS training and testing format.

A follow up to the Leader et al. (1996) study by Smeets, Leader, and Barnes (1997) attempted to refine the respondent-like procedure and to see if similar results could be obtained with young children. Results from their four experiments were somewhat mixed. On the one hand they found that the respondent training and MTS testing arrangement was successful in establishing equivalence responding in 76% of their younger (twelve 5-year-old preschoolers) participants. On the other hand, this finding was observed only when a simple-to-complex procedure was used. This procedure trains and tests for symmetry, transitivity, and equivalence separately. When all training and testing was conducted simultaneously, young children performed at only chance levels of responding.

Leader, Barnes-Holmes, and Smeets (2000) conducted a further follow up study that resulted in more consistent results than their 1997 attempt. In the 2000 report, all participants (N=15) demonstrated accurate performance on symmetry and equivalence tests (transitive tests were not included) using various stimulus arrangements. For example, in experiment 1, when four member stimulus classes were arranged such that A is correlated with B, B is correlated with C, and C is correlated with D (i.e. a linear protocol), tests for D-A, D-B, C-B, C-A, B-A relations were then conducted. In experiment 2 a one-to-many protocol was used where D-B, B-A, and B-C are trained while tests for D-A, D-C, A-B, and C-B were conducted. Finally in their 3rd experiment a many-to-one protocol was used where D-B, A-B, and C-B were correlated with one another and tests for D-A, D-C, B-C, and B-A were made. In addition to the use of non-sense syllables, equivalences had been demonstrated when teaching fraction and decimal relations (Leader & Barnes-Holmes, 2001a).

With the initial success of establishing equivalence responding using a respondent-like procedure there have been attempts to more directly compare the respondent and MTS training procedures. Leader & Barnes-Holmes (2001b) found that the respondent-like training was more effective in three out of four experiments. In experiments one, two, and three participants were taught pairs of relations using the respondent procedure and tested for emerged relations using MTS. Those same participants were then taught new stimulus relations using a MTS and tested using the same procedure. In all three experiments the respondent-like procedure was shown to be more effective as a training procedure.

Layng and Chase (2001) used a slightly different correlation procedure, in which the paired stimuli were presented at the same time. Simultaneously presented stimulus pairs remained on the computer screen for 3 seconds and were separated from other pairs by the time it took the participant to press a key on the keyboard. The key press started the next trial. This study also used a MTS testing format and found that for three out of four participants in experiment 1, and all three participants in experiment 2 responded accurately to equivalence test trials.

Clayton & Hayes (2004) compared the relative effectiveness of respondent-like and MTS training procedures. In their study, participants were exposed to some stimulus sets using MTS training and others using a respondent-like preparation similar to the one reported in Leader et al. (1996). Clayton & Hayes (2004) reported 73% of participants performed accurately on equivalence test trials for those relations trained using the correlation protocol opposed to 92% of participants performing accurately on equivalence test trials from the MTS training. The authors stated that their findings call into question those reported by Leader and Barnes-Holmes (2001) where the opposite results were found. There are considerations to be made when evaluating the disparity in results found in both reports. For one, Clayton & Hayes (2004) began their training procedure with the MTS trials followed by the same number of correlation training trials for a given participant. After training the MTS testing conditions were identical in appearance to the MTS training with the exception of no feedback being provided to participants. Contrast that to the training protocol employed by Leader & Barnes-Holmes who started with respondent-like training and then tested using MTS followed by MTS training and subsequent testing of new relations using MTS. The initial training via MTS in Clayton & Hayes may have inadvertently produced more effective MTS test performance.

More recently, Kinloch, McEwan, and Foster (2013) reported a training procedure that shared many of the same features as the series of studies by Leader et al. (1996, 1997, & 2000). They refer to their training protocol as a stimulus-pairing-observation procedure (SPO). When comparing the effects of correlation-training trials they found that participants exposed to 120 SPO trials responded more accurately in tests for equivalence using an MTS testing procedure than participants exposed to only 60 correlations trials.

In this, and all previous reports, a MTS testing procedure in which no feedback is provided after a comparison stimulus was used. Even in the absence of feedback and/or reinforcement in the MTS tests, it is possible that learning continues in testing based on the context established in the MTS protocol (Sidman, 1994 p.511-512; Barnes-Holmes, 2004; Clayton & Hayes, 2004). Minster, Elliffe, and Muthukumarasyamy (2011) demonstrated that learning in MTS tests could be demonstrated by removing the reinforcement contingency in MTS training. Their procedure started with training relations using a standard 1 sample/3 comparison MTS with reinforcement, however reinforcement was applied only to some of the stimulus sets leaving others as "ambiguous" trials for participants as whether or not their selection was correct. This procedure transitioned to a MTS maintenance block of trials where feedback was removed for all trials and participants had to respond as they did in the previous training to a predetermined criterion before moving to testing. In testing no feedback was provided. For 4 of the 5 participants accurate equivalence performance was observed for stimulus sets that did not receive reinforcement in training. The author reported this as a definitive demonstration that reinforcement is unnecessary for the development of equivalence responding. By contrast, Rehfeldt & Hayes (1998) argued that although conditions may be configured where a reinforcement contingency is unnecessary to establish stimulus classes, when reinforcement is coordinated with a participant's interaction with these stimuli their subsequent test performance may be enhanced.

The preceding correlation based alternatives to MTS training have shown that there are effective and efficient training methods that do not rely on sample/comparison plus feedback configurations. However, the correlation procedure does not provide a means to evaluate derived relations due to the lack of an overt response from participants. Because of this, a MTS procedure has often been used for evaluation. However, alternative evaluation procedures have been developed.

Alternative Evaluation Approaches

Fields, Reeve, Varelas, Rosen, and Belanich (1997) reported on a ‘Yes’/‘No’ procedure. In this configuration a participant was shown two stimuli, one after the other, followed by an opportunity to respond to either a ‘Yes’ or ‘No’ button. If the preceding stimulus pairs had been seen together or related through their coordination with other stimuli in training, then responses to the ‘Yes’ key would be correct. For all other pairs, where stimuli had not been presented together or were not related through their coordination with other stimuli in training, responses to the ‘No’ key would be accurate. The authors refer to the entire protocol as a “stimulus pairing/yes-no procedure”. Fields et al (1997) reported 10 of 18 participants successfully demonstrating equivalence responding using the ‘Yes’/’No’ protocol.

Fields and colleagues’ procedure is unlike the respondent-like procedure reported by Leader et al. (1996), in that the training conditions required an overt selection response by participants (i.e. ‘Yes’ or ‘No’) and included feedback based on the selection. For evaluation of possible derived relations the ‘Yes’/’No’ procedure is arranged with no feedback. This pairing protocol represents similar utility as MTS in that it can serve as the basis for both training and evaluation conditions.

The pairing method was later employed by Fields, Doran, and Marroquin (2009) to demonstrate equivalence performance given various response button labels (i.e. either ‘yes’ or ‘no’ / ‘same’ or ‘different’) along with elaborated training conditions to enhance transitive test trial performance. The elaborated training consisted of using both non-arbitrary words (e.g. Dog/Cat, Lion/Tiger) along with arbitrary nonsense words (e.g.Huv/Bon or Het/Zis). By having participants be trained with both arbitrary and non-arbitrary words the 'Yes'/'No' format provided further support of the findings reported earlier (Fields et al.,1997).

Hayes & Holmes (1997) proposed a similar protocol described as a relational evaluation procedure designed to allow participants to "confirm or deny the applicability of particular stimulus relations to sets of stimuli" (p.241). This procedure incorporated the training of a contextual cue stimulus that gains discriminative control over a "yes" or "no" response from participants when shown a pair of stimuli. For example, if an experimenter wanted to establish 'ZUS' as a contextual cue for "before", then participants would be presented with stimulus A followed by stimulus B and then given the opportunity to select between A-ZUS-B or B-ZUS-A. Selecting the A-ZUS-B option would be followed by reinforcement. This sequence could be repeated multiple times until ZUS is equivalent to "before". Once the contextual cue is established, it can be used in a sort of 'Yes' / 'No' evaluation task in a non-reinforcement test condition. For example, participants might be presented with novel stimuli C-D and C-ZUS-D on a computer screen and allowed to select from a 'Yes' and 'No' evaluation buttons. Given ZUS' prior training history selecting the 'Yes' button would indicate correct evaluation. In Hayes & Barnes' (1997) report, however, this proposed method had not been accompanied by empirical evaluation.

In an attempt to experimentally evaluate the proposal by Hayes & Barnes, Cullinan, Barnes, and Smeets (1998) introduced a "go/no go" procedure they call the precursor to the relational evaluation procedure (pREP). This preparation consisted of training conditions where two stimuli were presented, one after another for one second each, followed by a response opportunity where participants could either press a button (a "go" response) or omit a response (a "no go" response). Program consequences were presented depending on the participant's response and its correspondence to predetermined relations. After training, in evaluation conditions, stimulus pairs were presented in either symmetric or equivalence configurations and participants would either press or not press the response button to indicate if those stimulus pairs were in any way related. Cullinan et al. (1998) found that when pREP was used as training and testing only 1 of 5 participants responded accurately to tests for equivalence, compared to 4 of 5 participants responding accurately to tests for equivalence when MTS is used in training and testing. However, when MTS was used as the training format and pREP was used as the evaluation procedure 4 of 5 participants were accurate for tests of equivalence.

In a follow up study, Cullinan, Barnes-Holmes, and Smeets (2000) demonstrated better testing results than a traditional MTS configuration. However this was achieved only after participants were initially trained and tested using MTS and then later exposed to pREP. Under these conditions it may be suggested that the enhanced pREP performance is indicative of the notion that MTS testing itself is instructive even in the absence of feedback. In other words, MTS may have continued training effects even after feedback has been removed (Barnes-Holmes et al. 2004).

Cullinan, Barnes-Holmes, and Smeets (2001) attempted to see if adjusting the pre-training procedure and response labels (i.e. button press = same, no button press = different) would enhance accuracy in tests for equivalence. This study demonstrated accurate pREP tests for equivalence in the absence of MTS protocols when pretraining consisted of non-arbitrary stimuli paired with their arbitrary (i.e., abstract symbols) and response labels were ‘same’ and ‘different as opposed to ‘goes with’ and ‘does not go with’. To extend these findings, Smeets, Wijngaarden, Barnes-Holmes, and Cullinan (2004) demonstrated successful pREP training and testing performance when participants were exposed to a pre-training protocol using non-arbitrary stimuli (i.e. common words) and the addition of prompts in half of the training trials indicating whether or not to respond. Incorporating prompts to respond in a training procedure of this type is a rather unorthodox addition; however, the authors note that it is perhaps a limitation of their yes/no arrangement in that participants only responded overtly for ‘yes’ trials and omitted an overt response for those trials where stimuli are not designed to go together. This limitation is not found in Fields et al. (1997/2009) arrangement where you can select from either a ‘Yes’ or a ‘No’ option. Smeets et al. (2004) commented that a response requirement for ‘yes’ trials but not for ‘no’ trials differs from MTS in that with MTS a participant must indicate a response for each trial as it is the case that at least one of the comparison stimuli are designated to “go-with” or is “the same as” the sample.

There have been a series of studies that have demonstrated successful equivalence relations using a go/no-go procedure as both the training and evaluative structure. Debert et al. (2007, 2009) presented pairs of stimuli in training such that A1B1, for example, would be presented together as a compound stimulus for 4 seconds followed by the participant either clicking the stimulus pair to indicate that they go together or omitting the click response to indicate a non-exemplar. The training phase consisted of feedback in the form of points awarded to the participant if they clicked on stimulus pairs that conformed to one of the nine pre-arranged compounds. Go/no go testing omitted the feedback and recombined stimulus pairs to conform to symmetry, transitive, or equivalence relations. Debert et al. (2007) found that all six of their participants responded accurately to symmetry compounds and four of the six demonstrated transitive and equivalent relations. Debert et al. (2009) replicated findings from their previous study along with conducing a second experiment that used compound stimuli that were positioned either to the left or the right of the computer screen. Testing trials were considered correct if participants clicked the screen when stimulus compounds matched positional aspects of training and omitted a response when stimulus compounds did not arrange themselves in accordance to some trained compounds. However, the use of spatially arranged stimulus configurations poses difficulty for symmetrical and equivalence relations in that reversibility create positions that were not evident in training. For example if A1B1 and B1C1 are training compounds where their positional elements are relevant aspects of their relations, and in testing a C1A1 relation were to arise it would follow an equivalence re-combination but would not be considered spatially accurate. However, this appears to be a correct testing trial in Debert et al. (2009). Perhaps, it is the terminological use of symmetry, transitivity, and equivalence that impose undue barriers to the study of spatial relations.

Although adherents to the equivalence paradigm have suggested that the terminological barriers suggested here are unnecessarily imposed (Stromer, & McIlvane, 1993; Sidman, 1994) there is an alternative view. Relational Frame Theory (RFT) posits that arbitrarily applied derived relational responding can consist of relations of equivalence (coordination), as well as opposition, distinction, spatial, hierarchical, among others. Expanding the scope of potential ways in which stimuli can be related underscores how context comes to participate in how one would respond to stimuli. For example, if coordinated stimuli are of interest (i.e. equivalence) the reversibility of symmetrical relations are amenable. However, if spatial relations are of interest things that are experienced conventionally as up and down do not reverse unless some other training/experience is contacted. To address such difficulties, the terms mutual and combinatorial entailment (Hayes & Hayes, 1989; Hayes, Barnes-Holmes, & Roche, 2001) were proposed. Mutual entailment means that if A is related to B, then B is related to A and it is the context that comes to participate in how those relations are entailed. For example, in coordinated relations if A *is* B then B *is* A. However, if A is above B, then B is below A and thus not symmetrical in the same way as coordinated relations. Further, combinatorially entailed relations are what Hayes, Fox, Gifford, Wilson, Barnes-Holmes, & Healy (2001) refer to as "derived stimulus relations in which two or more stimulus relations (trained or derived) mutually combine", such that if in a given context, "A is related to B, and B is related to C, then as a result A and C are mutually related in that context" (p. 30). Using relations of coordination for example, the transitive and equivalence recombination of stimuli are adequate descriptions. However, spatial relations between these stimuli are not symmetrical. For example, if A is before B, B is not also before A. Thus for the present series of experiments, the language of mutual and combinatorial entailment will be adopted, with additional specifics added (e.g. mutually entailed symmetry relations) to permit the investigation of equivalence relations and non-equivalent spatial relations.

The primary purpose of this experimental series is to address the fact that, to date, there has not been a report of a non-reinforcement based correlation procedure used in training with a non-MTS testing protocol to establish and test for equivalence relations.

Nor has it been the case that the alternatives to the MTS protocols presented here (i.e. the correlation based training and yes/no evaluations) have been configured together. Further, to determine the applicability of the correlation training and yes/no evaluation procedure tin establishing spatial relations.

Experiment I

Subjects

Six undergraduate students enrolled at University of Nevada, Reno served as participants in this study. Participants were recruited using the psychology department sponsored research participant system. Compensation was delivered in the form of one hour of research credit, regardless of study completion or performance. Before the experimental session formally began the experimenter asked participants to confirm that their visual acuity was adequate for computer-based tasks reviewed the necessary consent materials.

Materials

All experiments were conducted using Internet assessable desktop and laptop computers connected to a password protected website that hosted the program. The pretraining, training, and evaluation procedures were controlled using a password protected customized ASP.net framework based web application. Experimental sessions occurred in a small (8’X10’) quiet room equipped with a desk, chair, and Dell desktop computer located in the Mack Social Sciences building on the campus of the University of Nevada, Reno.

Procedure

This study investigated the degree to which a correlation based training and sequentially ordered Yes/No Evaluation procedures resulted in derived relational responding.

Correlation Pretraining.

Before participants were exposed to the training and evaluative conditions with nonsense consonant-vowel-consonant (CVC) patterned words, they were exposed to a pretraining procedure designed to familiarize them with both the training and testing formats using common English words. Participants were asked to sit in front of the computer that displayed the following instructions:

> *Thank you for volunteering to participate in this experiment. A purpose of this experiment is to see how well people can detect when things "go-together". The experiment has several stages. The first stage is to help familiarize you with the procedure. In this first stage you will be presented with common words. It will be important to watch the screen closely during this first stage. At some points during this stage you will be asked if the two most recent words go together. To indicate if two words go together you will use the computers mouse to click the "YES" button – if the previous two words do not go together then click the "NO" button.*
> *Click the "START" button to begin.*

Once the participant clicked the start button the pre-training stimulus correlation procedure began. Word pairs designed to “go-together” were the following: Red/Blue, Dog/Cat, Circle/Square, Hotel/Motel, Shirt/Sweater, Hat/Cap, and Cow/Bull. Each pair was presented twice for a total of 14 ‘Yes’ trials. During correlations, the first stimulus is presented for 1 second followed by a within stimulus pair delay of .5 seconds, the second stimulus was then presented for 1 second. Each trial was separated by a 3 second between pair delay (i.e. a inter-trial interval) where the screen turned black. After the 3 second between stimulus pair delay, a button appeared in the center of the blackened screen that reads “Present Next Pair” (Table 3). The inclusion of the overt response requirement before the onset of a new correlation was similar to that used by Layng & Chase (2001) who incorporated a response requirement under the assumption that, although it may not guarantee that the participants view the next pair of stimuli, it may make it more likely given that they will have been oriented in that direction. The inclusion of this response requirement has the secondary benefit of situating the computer’s mouse cursor on the screen in a way that ensures that it does not inadvertently obscured the viewing of any of the stimuli to be presented.

Yes/No Evaluation Pretraining.

Once the 14 pairing trials had been completed the pretraining yes/no evaluation began with the following instructions.

> *Now it is time to see how well you remember the stimuli that go together. In this next stage of the experiment you will see pairs of words followed by a chance to indicate whether or not those two words "go-together". If you had just seen a pair of words that go together indicate this by selecting the "YES" button. Use the "NO" button for those pairs that you see that are not meant to go together. Remember that words that go together do not have to be presented in the same order.*
>
> *Click the "START" button to begin.*

The yes/no evaluation consisted of a similar stimulus presentation arrangement as the correlation procedure with the addition of an evaluative overt response requirement by the participant. A trial consisted of a stimulus presented for 1 second followed by a .5

second within stimulus pair delay. After the within stimulus pair delay the second stimulus was presented for 1 second. Immediately following the stimulus presentations a 'Yes' and a 'No' button appeared in the lower right and left hand portions of the computer screen, respectively. These buttons remained on the screen until the participant clicked either one of them. For stimulus pairs that appeared together in the pretraining, clicks to the 'Yes' button were recorded correct, and for those pairs that had not been presented together in the correlation training a click on the 'No' button were recorded as correct. In pretraining the participant was informed of their accuracy with a 'Correct' or 'Incorrect' label presented in the center the screen for 1 second following his or her response. 14 'Yes' and 14 'No' trials comprised the pretraining yes/no evaluation. Yes trials included two presentations of the 7 previously correlated pairs. No trials consisted of 14 presentations of new word pairs (i.e. Blue/Dog, Square/Red, Motel/Hat, Bull/Red, Sweater/Circle, Hotel/Cat, Cow/Hotel) that had not been correlated in pretraining. Table 3 shows the timing and stimulus presentation configuration for pretraining evaluation. To move from pre-training to correlation training, participants had to complete the 28 Yes/No trials with at least 80% accuracy. If a participant did not meet the minimum 80% criterion he or she was exposed to a further pretraining correlation and evaluation sequence for additional pretraining. The experimental program only permitted one additional pretraining sequence such that if a participant did not successfully completed pretraining within two attempts the experiment would end.

Correlation Training.

Upon completing the pretraining sequence participants were presented with the following instructions:

> *You are now ready for the next stage of the study. This stage is similar to the previous with one small change – the words you will see now are not real words. Your task will be to first watch to see which nonsense words go together. Following that you will be asked to determine if pairs of words you see "go-together" or not. Words that go together may not just be ones you've seen together or in the same order in the past but are still related. Also, you may or may not be told if you are making the correct selection, however the program is recording your performance and the better you do the sooner the study will be over.*
>
> *Click the "START" button to begin.*

Using the same temporal presentation parameters as in the pretraining condition, the participant was presented 20 correlation trials of the six designated stimulus pairs (i.e. 20 trials per pair across 6 pairs totaling 120 correlation trials). Stimuli in this, and all other subsequent conditions, were nonsense patterned CVC words (Table 2) and were presented in the center of the screen. One hundred and twenty correlations trials replicates the trial number configuration reported by Kinoch et al. (2013), who found 120 training trials resulted in enhanced equivalence test performance as compared to previous reports involving fewer trials. Participant response latencies of clicking the "present the next pair" button after the correlations trial represented the response measure during correlation training. Stimulus pairs were designed to fit the *linear series procedure* (Green and Saunders, 1998), which permits for the recombination of stimulus pairs to evaluate for mutually entailed symmetrical relations, combinatorially entailed transitive, and tests for combinatorially entailed equivalence.

Yes/No Evaluation.

After the 120 correlation trials, participants were presented with the following instructions:

> *Now you will be asked to determine if pairs of words you see "go-together" or not. The pairs may or may have not been seen together in the past or in the same order, however your task will be to determine if they are related to one another in any way. Some of the pairs do go together and others do not. Also, you may or may not be told if you are making the correct selection, however the program is recording your performance and the better you do the sooner the study will be over.*
>
> *Click the "START" button to begin.*

The testing sequence started with sequentially presenting the possible mutually entailed (M.E.) symmetrical, combinatorially entailed (C.E.) transitive, and C.E. equivalence tests for each of the three stimulus sets without feedback. Table 3 shows the temporal and stimulus configuration for evaluation trials. A total of 72 evaluation trials were presented. Yes and No trials consisted of 36 trials each, where each of the four possible derived relations (2 M.E. symmetrical, 1 C.E. transitive, and 1 C.E. equivalence relation) was presented 3 times per stimulus set. For M.E. symmetry trials, participants were presented with B1–A1, C1-B1, B2-A2, and C2-B2 trials. Evaluations of C.E. transitive relations consisted of pairs A1–C1, A2- C2, A3-C3. C.E. equivalence trials consisted of C1-A1, C2-A2, and C3-A3. Cross class pairs were used to create 'No' combinations during the evaluation conditions. For example, a 'No' M.E. symmetry trial was comprised of B1-A2, B1-A3, or B3-A1. C.E. Transitive 'No' trials were represented by presenting either A1, A2, or A3 followed by C1, C2, or C3 so long as neither of the two were from the same class. C.E. Equivalence 'No' trials used the same logic and reversed the order so that C stimuli were presented first followed by an A stimulus.

If after all 72 sequential evaluation trials were completed with 80% accuracy for each of the relations tested the experiment would end and the experimenter would debrief the participant. However, if any of the relations did not result in at least 80% accuracy the participant would be re-exposed to the 120 correlation training condition. After completing re-training, the participant would transition back to Yes/No evaluation and start with M.E. symmetry, then C.E. transitivity, and finally C.E. equivalence trials. The program was designed to allow participants to go through re-training up to three times. If after those attempts the participant did not complete the evaluation trials, then the experiment ended and the participant was debriefed.

Independent Variables

The independent variables were controlled by the computer program, and were designed to organize and present stimuli according to specified location and timing parameters.

Dependent Measures

Response accuracy in Yes/No evaluation was the primary dependent variable. In training, the latencies to respond to the "present the next pair" button were recorded, as well as the latencies to respond to either the 'Yes' or 'No' button in evaluative conditions.

Results and Discussion

Results from this study are graphically displayed as percent correct performance observed across the three evaluated derived stimulus relations for both 'Yes' and 'No' configured stimulus pairs (e.g., Figures 1, 2, 3, 4, 5, 6). Visual analysis of participant's evaluative performance is achieved by comparing the split bar ratio representation of each vertical bar as it relates to both the derived relation tested and the 80% correct minimum threshold used to establish the passing criteria. For example, P1-1's (*Figure 1*) performance for tests of M.E. symmetry (1) shows a split ratio of correct responses to Yes and No trials equaling 75% and thus not reaching the accuracy criteria. This split ratio is calculated by summing the combined accuracy for Yes and No trials (*Table 6*) and dividing by two (e.g., (.83+.67)/2 = .75). Percent correct figures progress from left to right with each subsequent tested derived relation. If a participant required retraining because the accuracy criteria was not achieved, subsequent derived relation labels on the x-axis indicate the number of testing sequence from 1 to 4.

Four of the six participants in experiment 1 demonstrated all three of the tested derived relations. On average, participants in this experiment required 2 retraining cycles for M.E. symmetrical performance to be observed, 3 for C.E. transitive, and 3 for C.E. equivalence (Table 12). No participant was observed to accurately derive all three relations after the initial training sequence. For those participants who only required one retraining (i.e. P1-1, P1-2) varied in their initial evaluation performance. P1-1 (***Figure 1***) responded to evaluation trials for all three relations with relative accuracy above chance levels and upon completing one retraining trial block, their subsequent evaluative performance remained consistent across all three relations at or above 90% accuracy. P1-2's (***Figure 2***) initial evaluative performance was variable with M.E. symmetrical performance being at 92% for combined Yes and No trials, C.E. transitive trials all being responded to as "not going together" and thus only accuracy was observed for No trials, and a similar pattern was observe for initial equivalence trials. After retraining, P1-2 did respond above 95% accuracy across the three relations. P1-6 (*Figure 6*) was the only participant in experiment 1 to require two retraining cycles and thus evaluative performance was recorded for the three relations on three occasions. Unlike any other participant in this experiment, P1-6 demonstrated C.E. transitive and C.E. equivalence relations before M.E. symmetrical relations where observed to be above the 80% correct criteria.

The remaining three participants (i.e. P1-3, P1-4, and P1-5) all contacted the total number of retraining sequences permitted by the program. Of these three participants, P1-5 (*Figure 5*) was the only participant to demonstrate accurate performance for the three relations. P1-5 showed a similar pattern to P1-2 in that they initially performed accurate M.E. symmetrical responding but required subsequent retraining to demonstrate combinatorially entailed transitive and equivalent relational responding. Additionally similar to P1-2's, responding to C.E. transitive and equivalence trials in the first two evaluative conditions was disproportionally allocated to the No response alternative. Meaning that for all the transitive Yes trials P1-5 indicated that these did "not go together" and for all but three Yes C.E. equivalence trials across the first two evaluative conditions were indicated as "not going together". Responding to these two combinatorially entailed relations did become accurate (i.e. over the 80% combined Yes and No accuracy criteria) in the third evaluative conditions, while M.E.symmetrical responding remained at or above criteria throughout all evaluative conditions. For the remaining participants (P1-3 & P1-4) accuracy was only observed to occur above the criteria for M.E. symmetrical and C.E. transitive trial formats. For P1-3 (Figure 3), symmetrical accuracy reached criteria after initial training and remained at or above the 80% criteria for the remainder of evaluative conditions. Accurate C.E. transitive performance for P1-3 was observed after the limit of four training/retraining cycles. P1-4 (*Figure 4*) showed accurate M.E. symmetrical responding after three training/retraining cycles and C.E. transitive performance was observed to meet the accuracy criteria in the final evaluative condition. Reviewing the kinds of errors made by participants who demonstrated all three of the derived relations in this study show that more false negative errors were observed. False negative errors are characterized by selecting the No alternative when the trail was a Yes evaluative trials. For those participants that demonstrated all three of the derived relations (*Table 13*) 24% of errors were observed to be false negatives as oppose to 9% of errors being false positives. However the evaluation trial structure used in this experiment has been reported to be easier than alterative structures (Smeets, et al. 2004) and thus the second experiment was conducted.

Experiment II

The aim of the second experiment was to evaluate the extent to which the sequential Yes/No evaluation trial configuration in experiment 1 may have enhanced derived relational responding. Previous work using different training and testing methods have investigated the differential effects of testing conditions that sequentially transition from symmetry to transitivity and/or equivalence (i.e. termed the *simple* protocol). This is opposed to what Smeets et al., (2004) call a *complex* protocol where symmetry and equivalence trials are intermixed in the testing condition. In experiment 5 of their report they found that when symmetry test trials preceded equivalence trials the participants performed more accurately, as opposed to arrangements where the tests for various relations where intermixed. In an attempt to determine if the relatively robust effects observed in experiment 1 were enhanced by the Yes/No evaluation trial configuration the present experiment seeks to employ a *complex* protocol similar to that of Smeets et al., (2004).

Subjects and Apparatus

Six undergraduate students were recruited using the same procedure as experiment one. Experiment 2 utilized the same ASP.net framework based web application accessed through Internet assessable desktop and laptop computers used in experiment 1. Experimental sessions occurred in a small (8'X10') quiet room located in the Mack Social Sciences building on the campus of the University of Nevada, Reno.

Method

The same instructions, trial configurations, and trial exposure used in experiment 1 was replicated in experiment 2. Participants were required to pass pre-training with at least 80% accuracy before moving to correlation training. All within and between stimulus pair delays were be kept at .5 and 3 seconds respectively.

Yes/No evaluation consisted of the same 72 trials split between 36 Yes and 36 No trials. However, these trials were presented in semi-random order to create a *complex* arrangement similar to what had been reported by Smeets et al. (2004). To create a complex presentation sequence the program was designed to mix M.E. symmetric, C.E. transitive, and C.E. equivalence trials so that each of the four possible relations (i.e. 2 M.E. symmetrical, 1 C.E. transitive, and 1 C.E. equivalent relation per stimulus set) across the three stimuli in a stimulus set were presented three times. To be considered semi-random the program did not repeat more than three times any stimulus pair, nor did it present all of a specific possible relation test (e.g. all the tests for transitivity) in sequential order as was done in experiment 1. The percent correct criterion was applied after the 72-evaluation trials had been completed. Upon completion of the 72 evaluation trials, the computer program calculated accuracy for each of the possible three derived relations separately. If the participant dis not achieve at least 80% accuracy for both 'Yes' and 'No' trials for any of the possible individual relations the participant was exposed to an additional block of 120 correlation training trials. Up to three re-trainings were permissible. If after that these trainings the accuracy criterion was not met in evaluation the experimental session ended and the participant was debriefed.

Results and Discussion

Graphical display and visual analysis of experiment two's results are to be interpreted in the same fashion as those from experiment I. Six participants completed experiment two with 5 of the 6 participants demonstrating accurate M.E. symmetrical, C.E. transitive, and C.E. equivalence within experimental parameters. The average number of retraining cycles necessary (*Table 12*) to demonstrate accurate M.E. symmetry above the 80% criteria was 1.4, for C.E. transitive it was 2.4, and 2.8 for C.E. equivalence trials.

As was the case with experiment I, all participants required at least one retraining. In experiment 2, there was one participant (i.e. P2-4) who required one retraining. P2-4 (*Figure 10*) demonstrated at or below chance responding across all three relations after the first training block of trials. After a further 120 retraining trials, P2-4 accurately responded to Yes and No evaluation trials across all three relational types. The majority participants (i.e. P2-1, P2-3, P2-5, and P2-6) required one training and 2 retraining cycles to demonstrate accurate responding at or above the criteria for the three evaluated for relation types. P2-1 (*Figure 7*) initially demonstrated complete accuracy for both M.E. symmetrical and C.E. transitive trial types, however, responded to the No response alternative to the majority of C.E. equivalence trials for the first two evaluative conditions. By the third evaluative condition trial set, P2-1 was able to maintain M.E. symmetrical and C.E. transitive accuracy as well as perform above the accuracy criteria for C.E. equivalence trials. P2-3 (Figure 9) showed a different pattern of acquisition with chance levels of responding being observed in the initial evaluative condition for all three of the relation types. M.E. symmetrical performance was observed after one retraining, although accuracy improvements to Yes trial types were observed for C.E. transitive and C.E. equivalence relations during this 2nd evaluation they had yet to reach the 80% criteria. P2-3 did, by the third evaluative sequence, demonstrated accurate performance across Yes and No trials for each of the three evaluation trial types. P2-5 (*Figure 11*) showed a similar acquisition pattern to P2-3 with chance responding in initial evaluation followed by M.E. systematical accuracy in the 2nd evaluation sequence and accuracy performance with C.E. transitive and C.E. equivalence trial types being observed to occur after three training/retraining cycles. P2-6 (*Figure 12*) is the only participant in this experiment to initially show better accuracy across Yes and No trial types for the C.E. equivalence relation than M.E. symmetrical and C.E. transitive trials, however, most of this accuracy is isolated to No trials and thus the participant considered the majority of these stimulus pairs to "not go together". As was the case with the previous two participants, P2-6 demonstrated M.E. symmetrical accuracy above the criteria after the first retraining sequence. Similarly, accurate C.E. transitive and C.E. equivalence performance was observed only after the third training/retraining sequence. The final participant, P2-2 (*Figure 8*) did not demonstrate criterion level accurate responding for any of the three relation types. However, P2-2 did show improvement and differentiated responding to Yes and No response alternatives by the forth evaluation sequence.

With regard to the general purpose of experiment two, it appears that evaluating for possible derived relations using a complex protocol was slightly better than was observed in experiment one. With five of the six participants in experiment two demonstrating all three of the evaluated for relations it is suggested that future research consider retaining the complex protocol. Comparisons between results observed in experiment one and two continue to show little difference. When comparing the average number of retraining cycles necessary (*Table 12*) between both experiments does not reveal a considerable difference between the two evaluation structures. Nor was there significance observed ($p<.05$) when comparing the response latencies between experiments one and two in evaluation conditions (*Table 11*). Furthermore, similar false negative (*Table 12*) results were observed with accurate performers in experiment II, with more false negative responses made (25%) as oppose to the false positive (19%) responses with participants who demonstrated all three of the derived relations.

Experiment III

The aim of experiment 3 was to evaluate the extent to which the training and evaluation structure in experiments 1 and 2 could be used to establish relations other than equivalence. Experiment three attempted to establish conditions where participants may come to relate stimuli spatially.

Subjects and Apparatus

A total of 10 participants were requited through the University of Nevada, Reno's psychology department sponsored research participant system. The same ASP.net framework based web application as described in the previous two experiments is used to configure experiment three.

Spatial Correlation & Evaluation Pre-training

Participants will first be presented with the following instructions:

> *Thank you for volunteering to participate in this experiment. A purpose of this experiment is to see how well people can detect when things are correctly placed. The experiment has several stages. The first stage is to help familiarize you with the procedure. In this first stage you will be presented with common words in specific positions on the screen. One word will be above a box in the center of the screen and the other will be placed below it. It will be important to watch the screen closely during this first stage. At some point you will be asked if the two most recent words are in the correct positions. To indicate if two words are placed correctly you will use the computer's mouse to click the "YES" button. If the two words are incorrectly placed then click the "NO" button.*

Following these instructions, the participant will begin a correlation pretraining using the following stimulus pairs designed to commonly represent spatial relations: heaven/hell, earth/sky, roof/floor, above/below, head/feet, attic/basement, and mountain/valley. Each pair was presented twice for a total of 14 correlation trials. These stimuli were presented in a visual configuration where one word is presented above a black box in the center in the screen, and the other word is presented below that box (Table 4).

During correlation trials, both stimuli were presented for 1 second. Each trial was separated by a 3 second between pair delay (i.e. a inter-trial interval) where the screen turns black. After the 3 second between pair delay, a button appeared in the center of the screen that reads "Present Next Pair". After pressing the "present next pair" button the next trial began. After the 14-correlation trials were presented the pre-training evaluation training began with the following instructions:

> *Now it is time to determine if the words are in the correct position. In this stage of the experiment you will see words in specific positions followed by a chance to indicate whether or not those two words are in the correct position. Select the "YES" button if you think the words are correctly placed. Use the "NO" button for those pairs that you see that are not correctly placed.*

Evaluation consists of a similar stimulus presentation arrangement as the correlation procedure with the addition of an evaluative response requirement. A trial consisted of both stimuli simultaneously presented for 1 second and immediately followed by the presentation of a 'Yes' and 'No' buttons in the lower right and left hand portions of the computer screen, respectively. These buttons remained on the screen until the participant selects one of the alternatives. For stimuli in the correct position, clicks to the 'Yes' button are recorded correct, and for those pairs not correctly placed selecting the 'No' button will be recorded as correct. Only in pretraining are the participant informed of their accuracy with a 'Correct' or 'Incorrect' label presented in the center the screen for 1 second following their responses.

Yes trials included two presentations of the 7 previously correlated pairs. No trials consisted of 14 presentations of word pairs that had not been correlated in pretraining. To move from pre-training to correlation training, participants have to complete the 28 Yes/No trials with at least 80% accuracy. If a participant did not meet the minimum 80% criterion he or she is re-exposed to the pretraining correlation and evaluation sequence again for additional pretraining. Participants are permitted to fail pre-training evaluation one time. For those participants who do not complete pre-training evaluation with at least 80% accuracy in either of their two attempts will be excused from further participation in the experiment.

Spatial Correlation and Evaluation

Upon completing the pretraining sequence, participants are presented with the following instructions:

> *You are now ready for the next stage of the study. This stage is similar to the previous with one small change – the words you will see now are not real words. Your task will be to first watch to see which nonsense words are placed above and below the black box. Following that you will be asked to determine if the words you see are correctly placed or not by pressing the Yes or No button. You may or may not be told if you are making the correct selection, however the program is recording your performance and the better you do the sooner the study will be over.*

Using the same temporal presentation parameters as in the pretraining condition, the participants are presented 20 correlation trials of the six designated stimulus pairs (i.e. 20 trials per pair across 6 pairs totaling 120 correlation trials). Stimuli in experiment 3 are the same as those used in experiments 1 and 2, and consist of nonsense patterned CVC words (Table 2).

Once the participant was presented with the 120 correlation trials of spatially oriented stimulus pairs the evaluative condition began. Evaluative trials are configured with the previously correlated stimuli in various combinations to create either Yes or No trials. To do this, each of the three stimulus sets has one designated Yes trial and two designated No trials. A total of 36 evaluation trials are conducted, with 18 combinatorially entailed Yes trials, 9 combinatorially entailed No trials, and 9 mutually entailed No trials (Table 5). Evaluation trials were semi-randomly presented across the three trial alternatives such that no one trial type is presented more than three times in succession and no one trial immediately repeats itself.

Upon completion of the 36 evaluation trials, the computer program calculated accuracy for each of the possible three derived relations separately. If the participant did not achieve at least 80% accuracy for 'Yes' and 'No' trials for any one of the possible relations the participant was exposed to an additional spatial correlation training sequence. Up to three re-trainings were possible. If after these trainings, the accuracy criterion was not met the experimental session ended and the participant was debriefed.

Dependent Measures

As was the case in experiments 1 and 2, response accuracy in Yes/No evaluation was the primary dependent variable. Response latencies were also collected in all instances when an overt response is necessary from the participant. In training, the latencies to respond to the "present the next pair" button was recorded, as well as the latencies to respond to either the 'Yes' or 'No' button in evaluative conditions.

Results and Discussion

Graphical display and visual analysis for the third experiment is slightly different than in experiments 1 and 2. Accuracy remained the dependent variable for each of the ten participants, and each vertical bar (*Figure 13* through *Figure 22*) represents the percent correct performance observed for each of the three possible derived relations. Because of the nature of spatial relations, Yes and No trials can not be combined within the same relation type and as such must be separated by relation type. Given this, each vertical bar in figures representing experiment three performers consists of either mutually or combinatorially No trials or combinatorially Yes trials. For example, P3-1 (*Figure 13*) shows the evaluative performance for each of the three relations across the two evaluation blocks necessary for this participant to fulfill the accuracy criterion. For this participant, at least 80% accuracy was not observed in any of the three relations after one training cycle, however, upon 120 additional correlation trials, this participant responded accurately to each of the three spatially organized trials.

Overall, 7 of the 10 participant (*Table 8*) demonstrated all three of the tested relations, and 8 of 10 accurately demonstrated mutually entailed No performance. However, only one of those participants (P3-9) accurately responded to M.E. No trials but did not do so for the other two tested relations. P3-9 (*Figure 21,*), accurate M.E. No trial performance is questionable given that it was observed during the second evaluative sequence but did not maintain in either the third or forth evaluative sequences. Therefore, for this experiment, it is the case that participants that demonstrated one testing relation demonstrated the other two, though not necessarily at the same time. P3-2 (*Figure 14*) met criteria for M.E. No trials prior to doing so for C.E. No and Yes trial types.

Two participants (P3-3 & P3-4) were observed to reach accuracy criteria after one correlation training. Of the participants that did not reach accuracy criteria (P3-5, P3-6, P3-9), two (P3-5 *Figure 17*, P3-6 *Figure 18*) showed progressively better accuracy for each relation type after retraining. This suggests that had the program permitted further retraining these participants may have eventually reached the accuracy criteria.

Responses latencies (*Table 11*) collected in this experiment during evaluation trials did not show significant ($p < .05$) differentiations between this or the previous two experiments. There was a negligible difference between false negative and false negative responding observed among accurate participants in this third study as oppose to what had been observed in experiments one and two (*Table 12*). A further comparative analysis was conducted concerned with there was a relationship between errors made (*Table 10*) and the stimuli involved. In experiment three (as was also the case in experiments one and two) there was no significance detected ($p < .05$) between errors made and them being correlated with a particular stimulus set.

These data suggest that the correlation training and yes/no evaluation configuration is a suitable procedure for establishing spatial relations and testing for possible derived spatial relations. It can be assumed that accurate performance in yes/no evaluation of derived spatial relations is attributable to the same conditions that established accurate derived M.E. symmetry, C.E. transitive, and C.E. equivalence performance in experiments one and two. However, there is a potential alternative explanation for the results observed in experiment three. Namely, that no derivation occurred or was necessary for accurate performance to occur for M.E. No or either C.E. Yes or No trials. For instance, it is possible that because an A stimulus were observed in training to always be above a B stimulus, and a C stimulus were always observed to be below a B stimulus a participant in the evaluation conditions could respond only the position of one stimulus regardless of the other stimulus present. This means that if in a M.E. No trial, instead of responding to B above A as a relation the participant could have responded accurately by observing that the A stimulus was positioned below the black bar instead of above without regard to the B stimulus. Further, in C.E. Yes trials the participant could presumably respond accurately by noticing that an A stimulus is above the black bar, instead of deriving a relations between A & C stimuli. With the data collected in experiment three there is no definitive way to conclude if derivation was necessary for accurate evaluation performance and thus represents an important consideration for future investigations into relations of this type (i.e. not equivalent relations) and the methods employed to establish and test for possible derived relations.

General Discussion

With 16 of the 22 participants in these three experiments demonstrating all three of the tested derived relations and 20 of the 22 demonstrating mutually entailed relations, the correlation training and Yes/No evaluation arrangement appears to be an effective procedural alternative to MTS. With the majority of participants in each of the three experiments accurately demonstrating tests for derived relations, the present results contributed to the other attempts to create alternative training (e.g. respondent-like), and testing (e.g. go/no-go, Yes/No) alternatives to MTS. Further, this series of studies was able to establish and test for both equivalent and non-equivalent spatial relations using the same procedures.

As reliable as the MTS protocol has been for training and testing relations among stimuli it is an artificial configuration that has little correspondence to how an individual ordinarily interacts with their environment. Correlations among stimuli, on the other hand, are a homologous aspect of a human's everyday experience. Whether intentionally, as in marketing campaigns, or by happenstance, stimuli occurring in temporal and/or spatial proximity is a ubiquitous aspect of our everyday interactions with the environment. Further, procedures that seek to model natural happenings may orient our attention to important aspects of organisms' interactions with their environment. For instance, the present series of experiments demonstrated how just watching stimuli in temporal proximity readily resulted in derived relational responding. This observation offers support for further research where correlation training could be embedded in the context of a game for the purposes of academic instruction. Games, designed to supplement the didactic instruction a student receives in school are becoming more popular (Morford et al., 2014), and it is encouraging to consider how stimuli could be systematically correlated in the context of a game so as to bring about derived relations that could later be assessed in the context of general education testing. Although in the present form the current methodology does not mimic a game context the underlining arrangement of systematically correlating pairs of stimuli could easily be embedded in a game ameliorating the tedium required by the present task.

A further advantage of the correlation and Yes/No evaluation method employed herein is the possibility of incorporating transformation of stimulus function operations. Transformation of stimulus function (Hayes, 2001) is the RFT concept that psychological functions adherent to a stimulus object can transfer to other stimulus objects in accordance with underlying derived relations. For example, Dougher et al. (2007) demonstrated size comparative relations between three stimuli (i.e. A<B<C) through MTS training and then applied a mild physical aversive (shock) to one middle member of the linear sequenced stimuli. In subsequent testing conditions, participants' skin conductance was monitored and it was shown that for the majority of participants' skin conductance was observed to correlate in accordance with the derived stimulus relations taught in training. Although MTS was a suitable method for establishing these relations in Dougher et al.'s study it is reasonable to assume that the correlation training structure would be amenable to the addition of other correlated stimulus functions and the Yes/No evaluative structure suitable in detecting how those functions transfer through their relations with one another. Further, an evaluative context could be arranged such that the stimulus functions attributed to stimuli in training would not need to be employed in testing. If in training, for example, stimulus pairs were correlated in accordance with smaller/bigger relations and a shock was applied to the participant when the designated "small" stimulus is presented, the participants could be asked in the evaluation condition to indicate which of the following would result in more "pain" without having to continue to apply the shock or measure a physiological response.

A further benefit of the correlation and yes/no evaluation methodology is the adjustability to accommodate various relations like the spatial type demonstrated in experiment three. Having the only precondition for training be that stimuli are correlated proximally to one another permits considerable accommodations for arranging stimuli in accordance with various relation types. However, the potential for explaining the results of experiment three without appealing to derived relational responding tempers an exuberant appeal to the study of non-equivalent relations with the methods used herein.

Although derivation is not excluded as a plausible explanation for how A and C stimuli were related to one another spatially in experiment three, the possibility that a participant was responding to stimuli in isolation is equally plausible. Given that a participant could have responded accurately to either Yes or No trials in experiment three by learning that A is always above or C is always below suggests that the spatial relation itself may pose investigative barriers. It should be noted that if a MTS format was configured such that comparison stimuli were arranged either above or below the sample does not eliminate the concern that derivation is not necessary to respond accurately in testing. The concern may not come from the procedure used, but rather the lack of a symmetrical relation among stimuli arranged spatially. Because stimuli that are arranged above other stimuli do not share the same symmetrical properties that equivalent stimuli do, the possibility for combinatorial derived relations appears limited. It is for this reason that the findings of experiment three come with caution for future researchers interested in arranging non-equivalent derived relations of various types. It will be necessary to demonstrate that correct mutually and or combinatorial entailed performance is attributable to derivation and not artifacts of other aspects of the experimental conditions. For instance, it would be possible to establish a relationship between a symbol, such as a square, and the term “above”. After this correlation is established, a participant could enter into the same equivalence training as in experiments one and two. Following equivalence training the A stimulus could be correlated with the square (i.e. a contextual stimulus representing “above”). Derived spatial relations could be demonstrated if the participant selected the Yes alternative in testing conditions when the B stimulus was above the line and the square was present. The same could be attempted with the C stimulus and thus allowing for derived combinatorial entailment between the A and C stimuli.

There are other considerations for future research that may serve to refine the current methodology. For one, given the lack of a response requirement for the training relations there is no direct measure of the accuracy with which participants evaluated the training pairs. Although accuracy can be assumed to have been present for training pairs for those participants who later responded accurately to derived relations in Yes/No evaluation, it was not directly assessed and it is suggested that tests for training pairs be incorporated in Yes/No evaluation conditions. Additionally, the way the present methodology is arranged does not allow for a time series analysis of the development of derived relational responding. A potential remedy to this would be to incorporate Yes/No evaluation trials within correlation training, similar to a multiple probe design (Gast, 2010). This would also align with the suggestion proposed by Green & Saunders (1998), in their review of equivalence work.

These considerations notwithstanding, the present experiments appear to be a fruitful area for continued research on alternatives to MTS as well as to assess the extent to which other areas of derived relational responding are amenable to correlation training and Yes/No evaluation.

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Tables and Figures

Table 2: Stimuli used in training and evaluation conditions along with correlation pairs used in training

	A1	CUZ	Pair 1: *A1 – B1*
Set 1	*B1*	PIP	Pair 2: *B1 – C1*
	C1	FIP	
	A2	ZAC	Pair 3: *A2 – B2*
Set 2	*B2*	DUZ	Pair 4: *B2 – C2*
	C2	VAM	
	A3	ZID	Pair 5: *A3 – B3*
Set 3	*B3*	JOM	Pair 6: *B3 – C3*
	C3	XAD	

Table 3: Training and evaluation sequence

Correlation Training	**Stimulus 1** (1 second)	.5 second	**Stimulus 2** (1 second)	3 second ITI	***Present the Next Pair***
Yes/No Evaluation	**Stimulus 1** (1 second)	.5 second	**Stimulus 2** (1 second)	Evaluation Yes No	***Present the Next Pair***

Table 4: Visual configuration of spatial relation correlation training trial

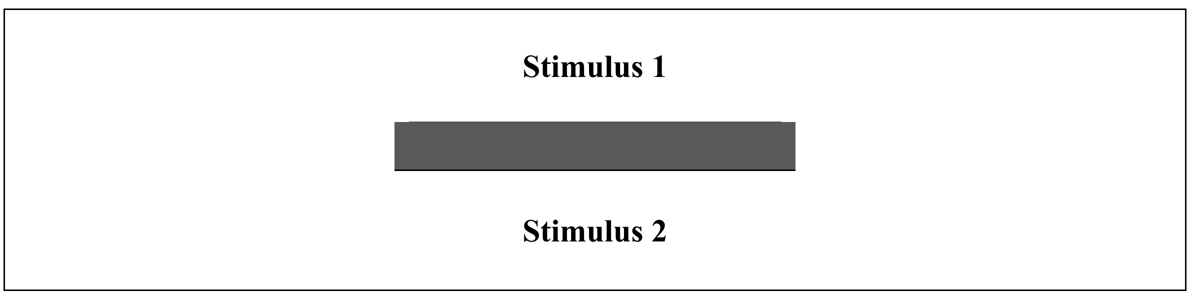

Table 5: Trial configuration during experiment 3. Stimulus pairs are represented in the spatial position observed in training and evaluation conditions

Pair 1	*Pair 2*	*Pair 3*	*Pair 4*	*Pair 5*	*Pair 6*
A1 B1	B1 C1	A2 B2	B2 C2	A3 B3	B3 C3
Mutually Entailed No Trials					
B1 A1		B2 A2		B3 B3	
Combinatorial Entailed Yes Trials					
A1 C1		A2 C2		A3 C3	
Combinatorial Entailed No Trials					
C1 A1		C2 A2		C3 A3	

Table 6 **Experiment 1 percent correct performance in evaluation condition**

Evaluation Condition	*Trial Type*	*P1*	*P2*	*P3*	*P4*	*P5*	*P6*
M.E.Sym 1	Yes	83%	83%	72%	78%	89%	83%
	No	67%	100%	94%	44%	100%	67%
C.E.Trans 1	Yes	67%	0%	22%	22%	0%	67%
	No	67%	100%	78%	44%	100%	78%
C.E.Equiv 1	Yes	61%	22%	11%	11%	22%	0%
	No	67%	100%	67%	35%	100%	67%
M.E. Sym 2	Yes	89%	100%	83%	78%	100%	72%
	No	89%	100%	100%	56%	100%	83%
C.E.Trans 2	Yes	89%	100%	56%	44%	0%	84%
	No	100%	89%	100%	56%	100%	100%
C.E.Equiv 2	Yes	89%	100%	56%	22%	11%	89%
	No	100%	100%	67%	44%	100%	100%
M.E. Sym 3	Yes	NA	NA	94%	100%	100%	100%
	No	NA	NA	100%	67%	100%	94%
C.E.Trans 3	Yes	NA	NA	22%	56%	56%	100%
	No	NA	NA	78%	56%	100%	89%
C.E.Equiv 3	Yes	NA	NA	11%	11%	67%	89%
	No	NA	NA	67%	56%	100%	100%
M.E.Sym 4	Yes	NA	NA	89%	100%	100%	NA
	No	NA	NA	89%	72%	100%	NA
C.E.Trans 4	Yes	NA	NA	78%	78%	89%	NA
	No	NA	NA	89%	89%	100%	NA
C.E.Equiv 4	Yes	NA	NA	56%	44%	100%	NA
	No	NA	NA	78%	67%	100%	NA

Note: Percent correct performance for each of the six participants in experiment one. Scores are separated by both relation evaluated (Symmetry, Transitivity, or Equivalence) and by trial type (i.e. Yes or No)

Table 7 **Experiment 2 percent correct performance in evaluation conditions**

Evaluation Condition	***Trial Type***	*P1*	*P2*	*P3*	*P4*	*P5*	*P6*
M.E.Sym 1	Yes	100%	67%	72%	78%	61%	56%
	No	100%	44%	38%	56%	56%	61%
C.E.Trans 1	Yes	100%	22%	33%	44%	44%	44%
	No	100%	44%	78%	56%	56%	56%
C.E.Equiv 1	Yes	22%	33%	33%	33%	11%	44%
	No	89%	56%	56%	33%	100%	100%
M.E.Sym 2	Yes	100%	100%	67%	100%	100%	89%
	No	100%	0%	100%	100%	61%	72%
C.E.Trans 2	Yes	100%	100%	44%	89%	56%	78%
	No	100%	0%	100%	100%	78%	78%
C.E.Equiv 2	Yes	22%	100%	33%	100%	67%	67%
	No	100%	0%	78%	89%	56%	56%
M.E.Sym 3	Yes	100%	72%	89%	NA	100%	90%
	No	100%	67%	94%	NA	100%	94%
C.E.Trans 3	Yes	100%	56%	78%	NA	100%	100%
	No	100%	56%	89%	NA	89%	89%
C.E.Equiv 3	Yes	100%	44%	84%	NA	100%	89%
	No	100%	56%	89%	NA	100%	89%
M.E.Sym 4	Yes	NA	78%	NA	NA	NA	NA
	No	NA	78%	NA	NA	NA	NA
C.E.Trans 4	Yes	NA	78%	NA	NA	NA	NA
	No	NA	67%	NA	NA	NA	NA
C.E.Equiv 4	Yes	NA	67%	NA	NA	NA	NA
	No	NA	78%	NA	NA	NA	NA

Note: Percent correct performance for each of the six participants in experiment two. Scores are separated by both relation evaluated (Symmetry, Transitivity, or Equivalence) and by trial type (i.e. Yes or No)

Table 8 **Experiment 3 percent correct performance in evaluation conditions**

Evaluation Condition	*P1*	*P2*	*P3*	*P4*	*P5*	*P6*	*P7*	*P8*	*P9*	*P10*
M.E. No 1	77%	55%	100%	89%	22%	44%	44%	56%	44%	67%
C.E. No 1	44%	66%	89%	89%	28%	11%	44%	66%	56%	11%
C.E. Yes 1	67%	28%	94%	94%	56%	33%	56%	56%	44%	50%
M.E. No 2	89%	89%	NA	NA	33%	56%	56%	89%	89%	89%
C.E. No 2	94%	67%	NA	NA	22%	44%	56%	89%	56%	100%
C.E. Yes 2	89%	67%	NA	NA	33%	22%	72%	89%	72%	83%
M.E. No 3	NA	89%	NA	NA	33%	44%	89%	NA	67%	NA
C.E. No 3	NA	89%	NA	NA	56%	56%	89%	NA	56%	NA
C.E. Yes 3	NA	83%	NA	NA	39%	39%	89%	NA	78%	NA
M.E. No 4	NA	NA	NA	NA	67%	56%	NA	NA	44%	NA
C.E. No 4	NA	NA	NA	NA	56%	78%	NA	NA	56%	NA
C.E. Yes 4	NA	NA	NA	NA	61%	56%	NA	NA	78%	NA

Note: Percent correct performance for each of the 10 participants in experiment three. Scores are separated by relation evaluated (Mutually Entailed No, Combinatorial Entailed No, or Combinatorial Entailed Yes)

Table 9. **Error index for experiments 1 and 2**

		Stimulus Set 1			**Stimulus Set 2**			**Stimulus Set 3**		
		M.E.Sym	C.E.Trans	C.E.Equiv	M.E.Sym	C.E.Trans	C.E.Equiv	M.E.Sym	C.E.Trans	C.E.Equiv
Exp 1	*SD*	1.8	3.6	2.9	1.3	3.9	3.6	1.0	3.1	2.8
	% of Errors		28%			41%			33%	
	P-value		.494			.271			.038*	
Exp 2	*SD*	1.6	2.7	2.1	2.2	2.2	1.2	3.5	2.0	1.2
	% of Errors		29%			32%			38%	
	P-value		.259			.858			.31	

Note: Error index provides a summary of the distribution and percentage of errors made per stimulus set for the evaluated derived stimulus relations. (P <.05) , * significance observed at the <.05

Table 10. **Error index for experiment 3**

		Stimulus Set 1			**Stimulus Set 2**			**Stimulus Set 3**		
		M.E. No	C.E. No	C.E. Yes	M.E. No	C.E. No	C.E. Yes	M.E. No	C.E. No	C.E. Yes
Exp 3	*SD*	2.7	2.6	3.7	3.0	2.3	4.1	2.3	2.7	4.6
	% of Errors		31%			36%			34%	
	P-Value		.231			.199			.149	

Note: Error index provides a summary of the distribution and percentage of errors made per stimulus set for the evaluated derived stimulus relations. (P <.05)

Table 11. **Evaluation condition response latencies**

	Experiment 1	Experiment 2	Experiment 3
Average Response Latency (seconds)	1.32	1.04	1.91
P-value	.589		

Note: Average response latencies for each experiment's evaluation conditions. P-value is calculated between those participants who performed accurately with each of the derived relations and those participants that did not perform at least one of the evaluated for relations. No significance was detected at <.05

Table 12. **Average number of retraining necessary to observe an evaluated for derived relation**

	M.E. Sym.	C.E. Trans.	C.E. Equiv.
Experiment 1	1.6	2.8	2.5
N-value	(5)	(5)	(4)
Experiment 2	1.4	2.4	2.8
N-value	(5)	(5)	(5)
	M.E. No	**C.E. Yes**	**C.E. No**
Experiment 3	1.9	2	2
N-value	(8)	(7)	(7)

Notes: The number of retraining conditions necessary for those participants that were observed to have demonstrated one of the three evaluated for derived relations. N-values represent the number of participants who were observed to have demonstrated the indicated derived relation.

Table 13**: False negative and positive analysis for participants who performed accurately to all derived relations**

	Experiment 1	*Experiment 2*	*Experiment 3*
False Negative total	24%	25%	20%
False Positive total	9%	19%	22%

Note: False negative responses were those where a participant responded to the No alternative when the trial was designated as a Yes trial. False positives are the inverse. Participant data was only included if they performed all three of the derived relations.

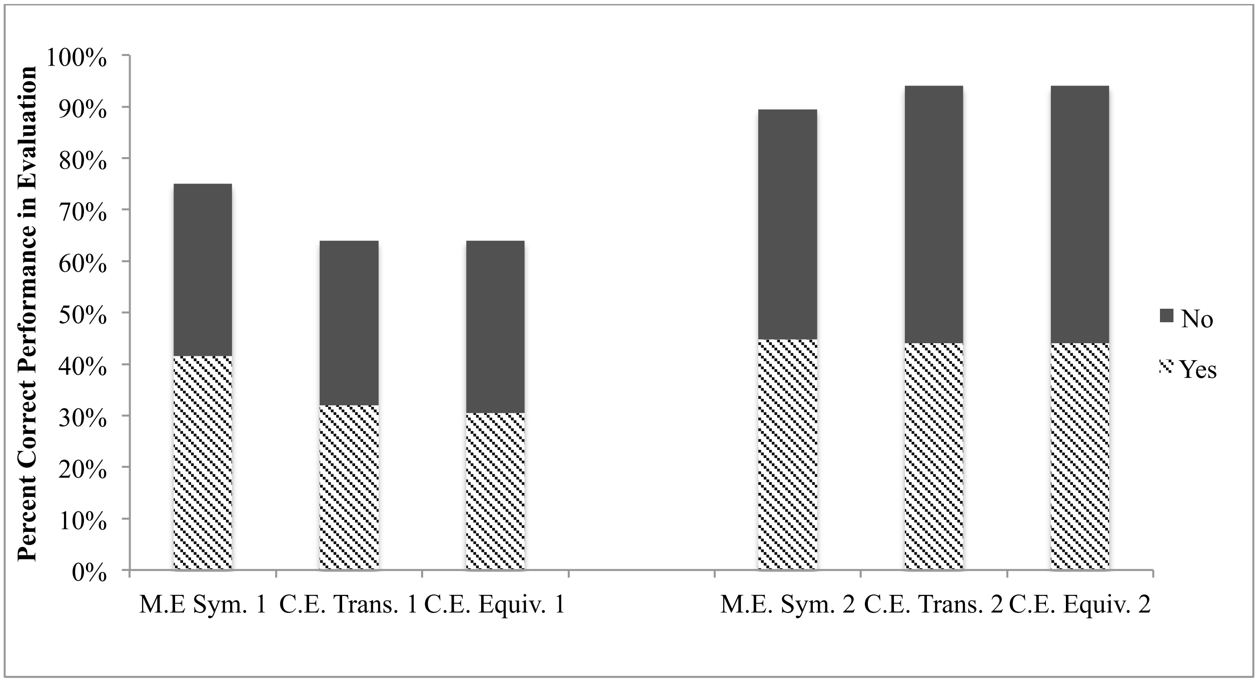

Figure 1. **Percent correct performance observed across evaluation conditions for participant 1, experiment 1.**

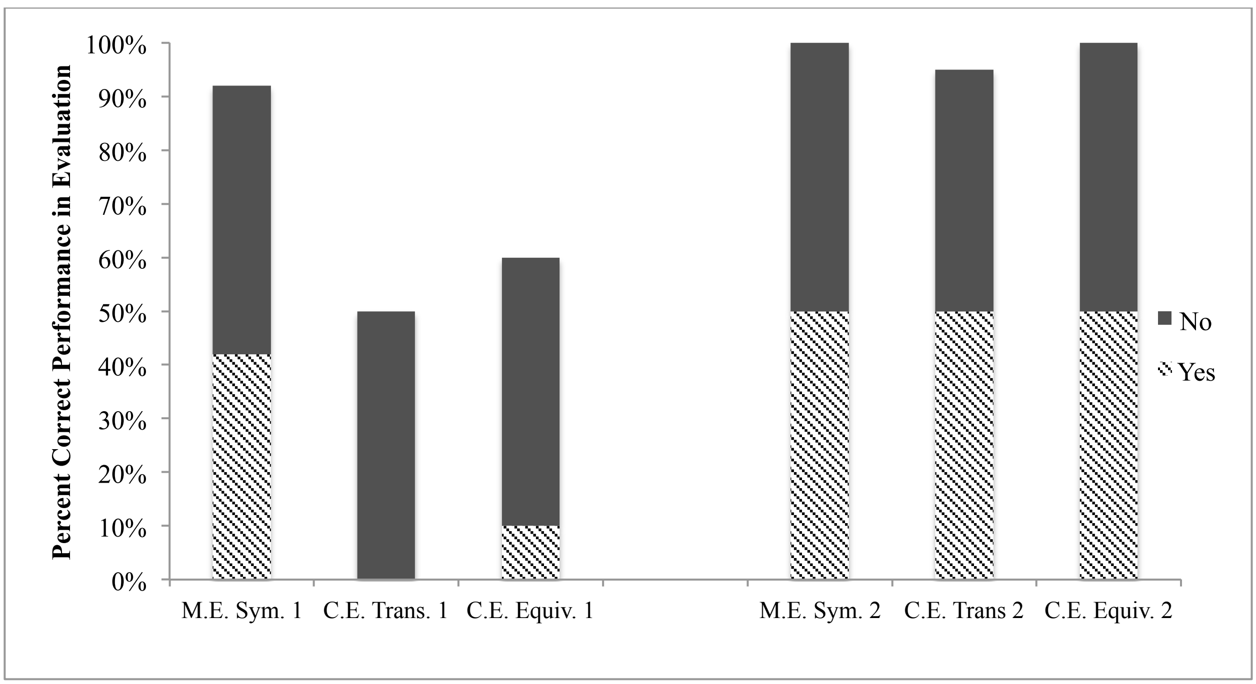

Figure 2 **Percent correct performance observed in evaluation conditions for participant 2, experiment 1**

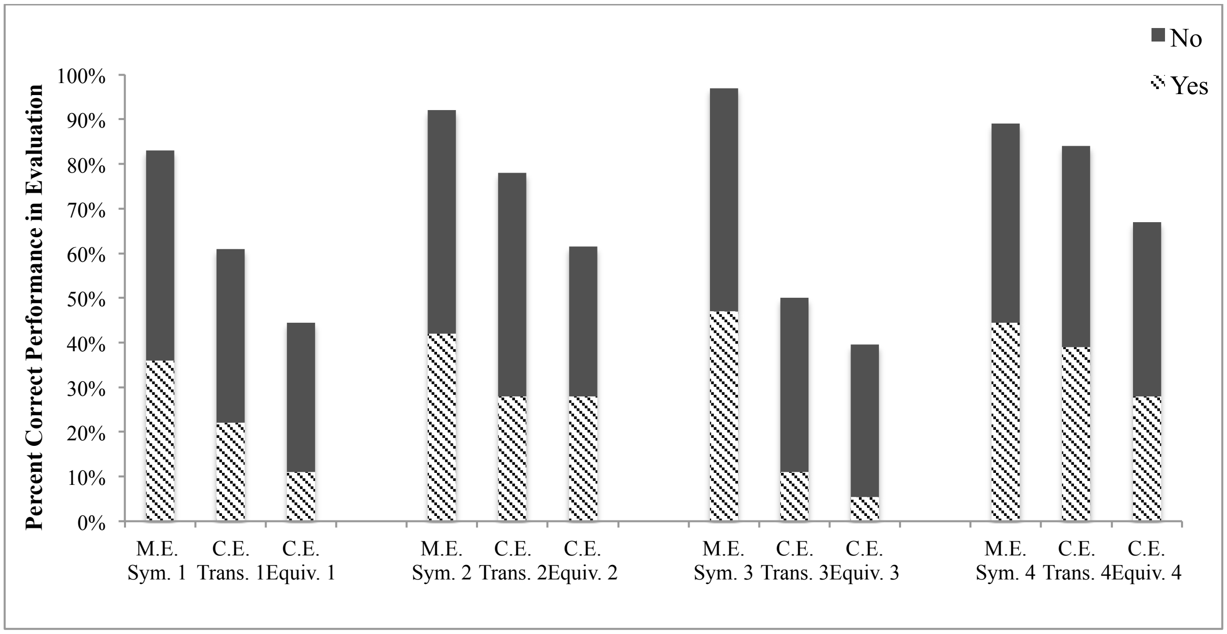

Figure 3 Percent correct performance observed in evaluation conditions for participant 3, experiment 1

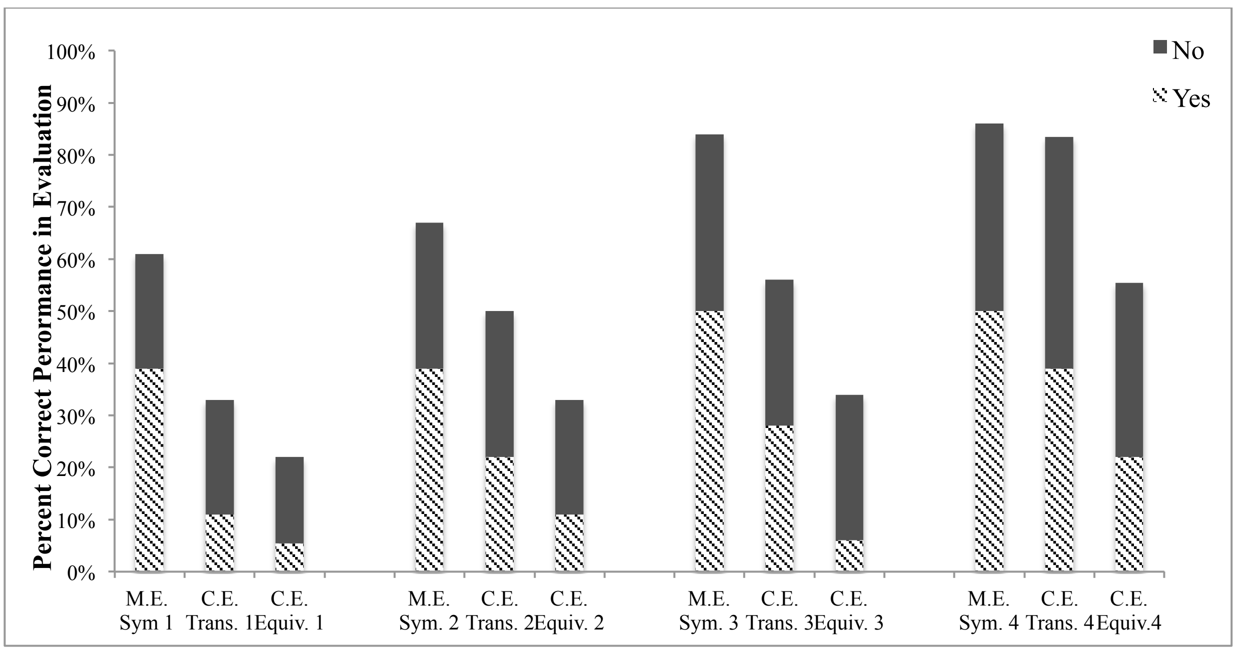

Figure 4 **Percent correct performance observed in evaluation conditions for participant 4, experiment 1**

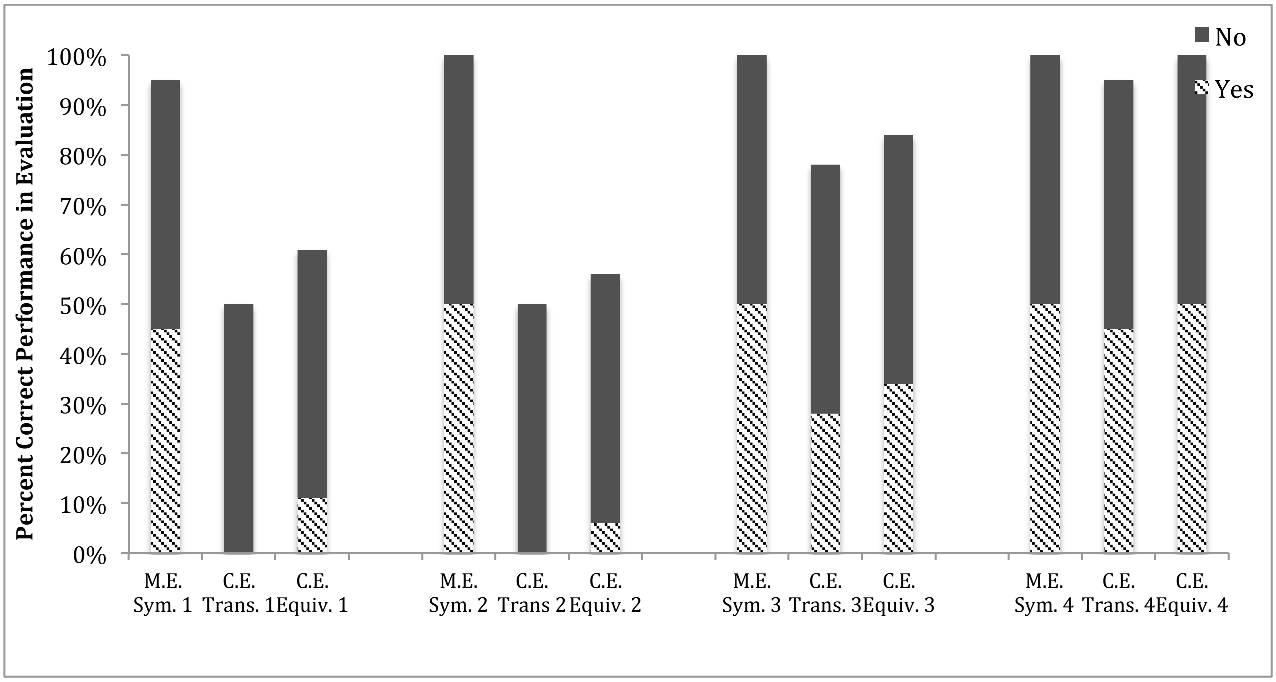

Figure 5 **Percent correct performance observed in evaluation conditions for participant 5, experiment 1**

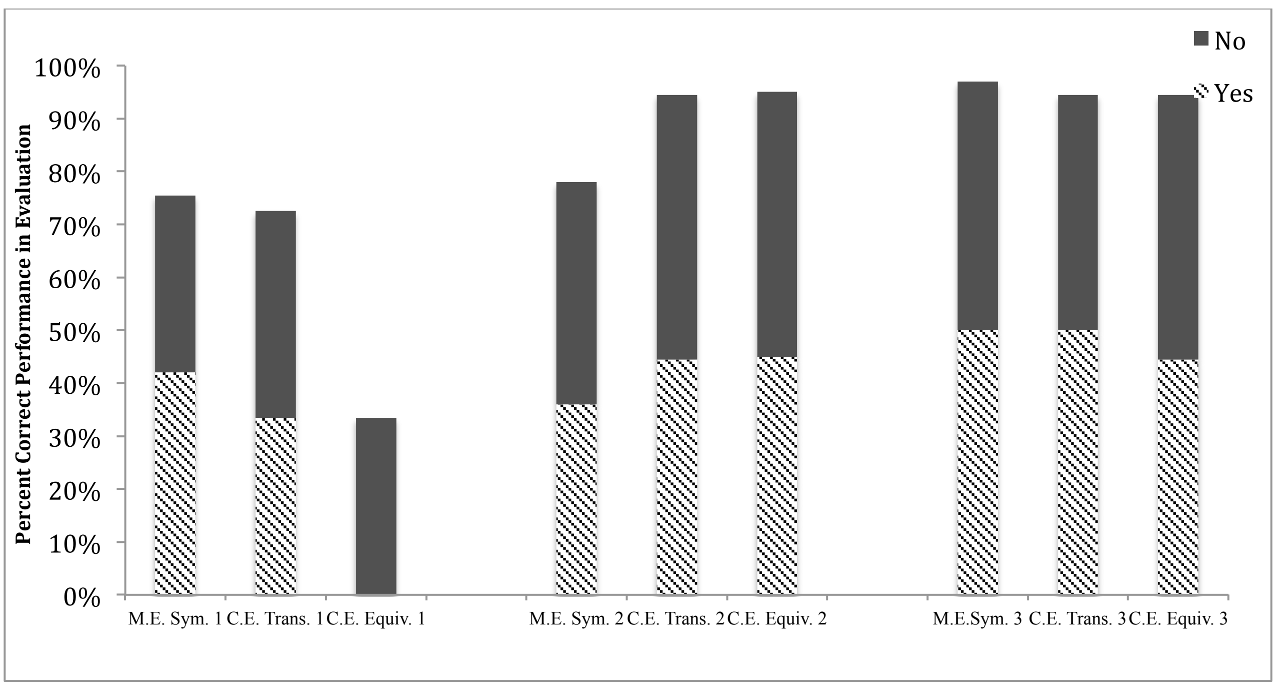

Figure 6 **Percent correct performance observed in evaluation conditions for participant 6, experiment 1**

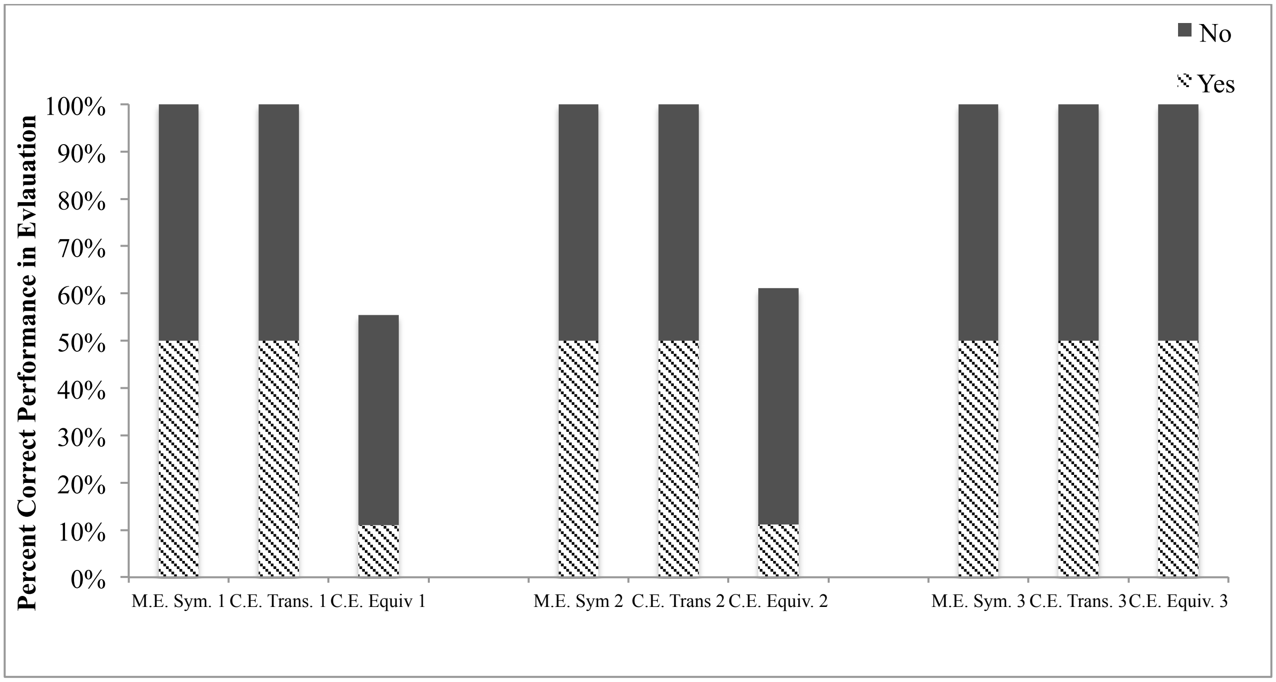

Figure 7 **Percent correct performance observed in evaluation conditions for participant 1, experiment 2**

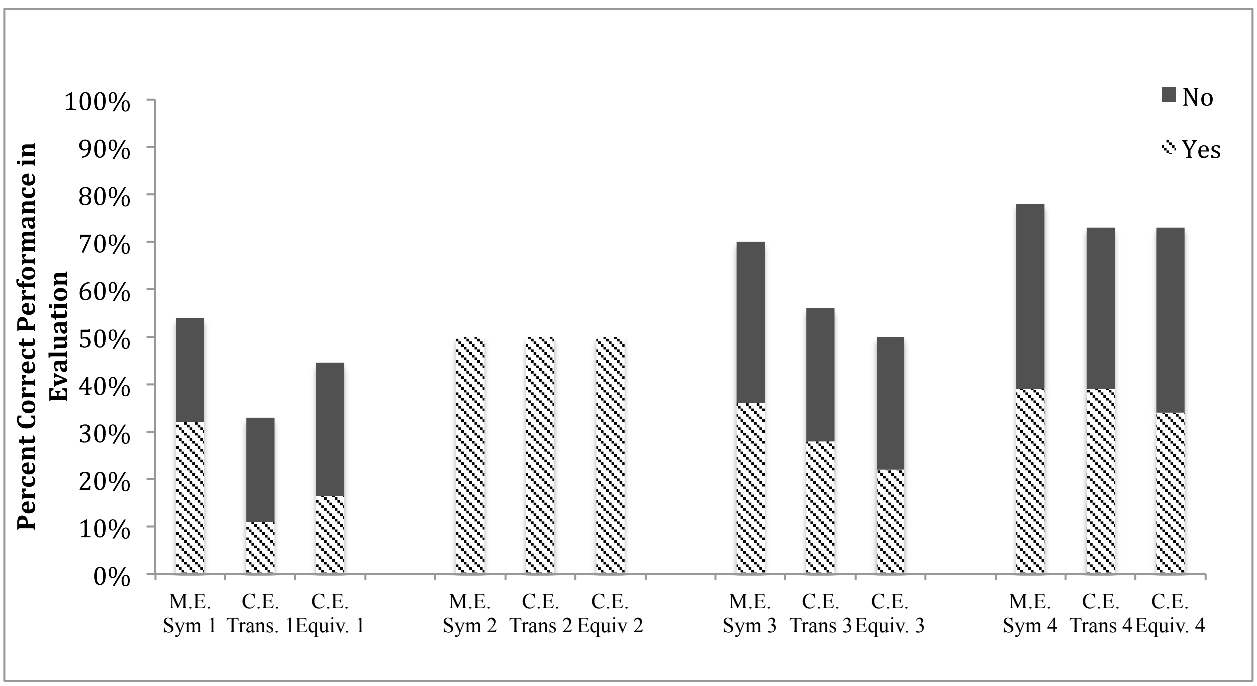

Figure 8 **Percent correct performance observed in evaluation conditions for participant 2, experiment 2**

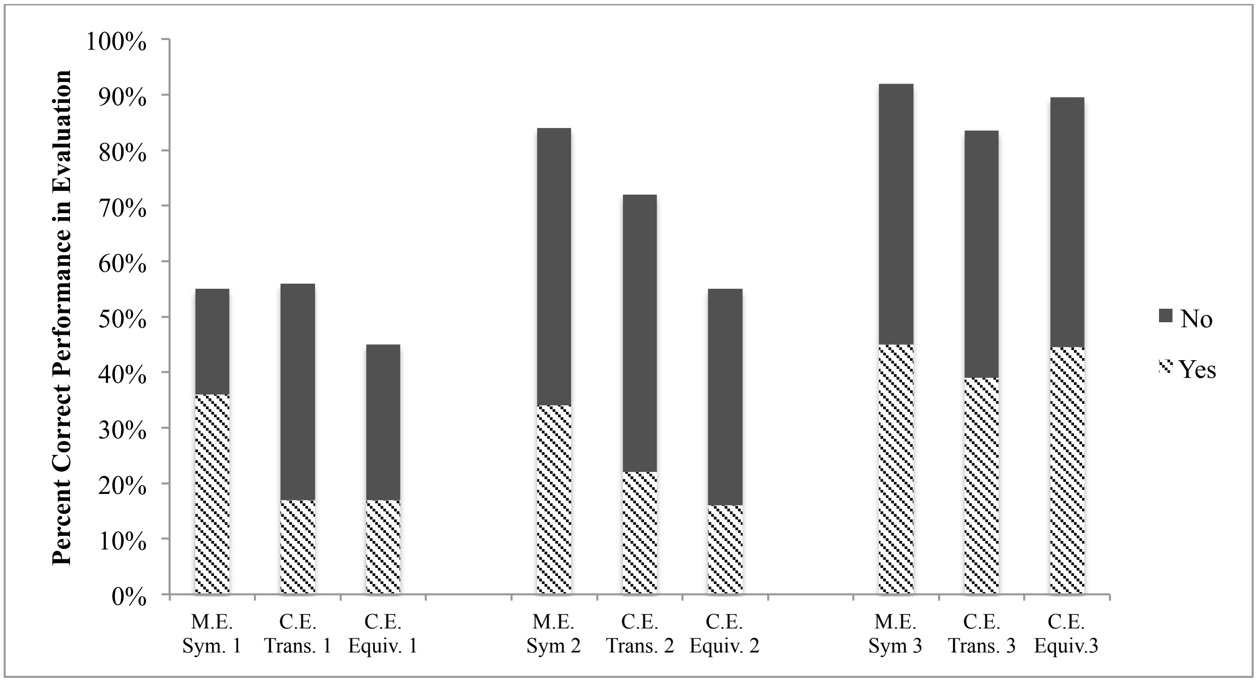

Figure 9 Percent correct performance observed in evaluation conditions for participant 3, experiment 2

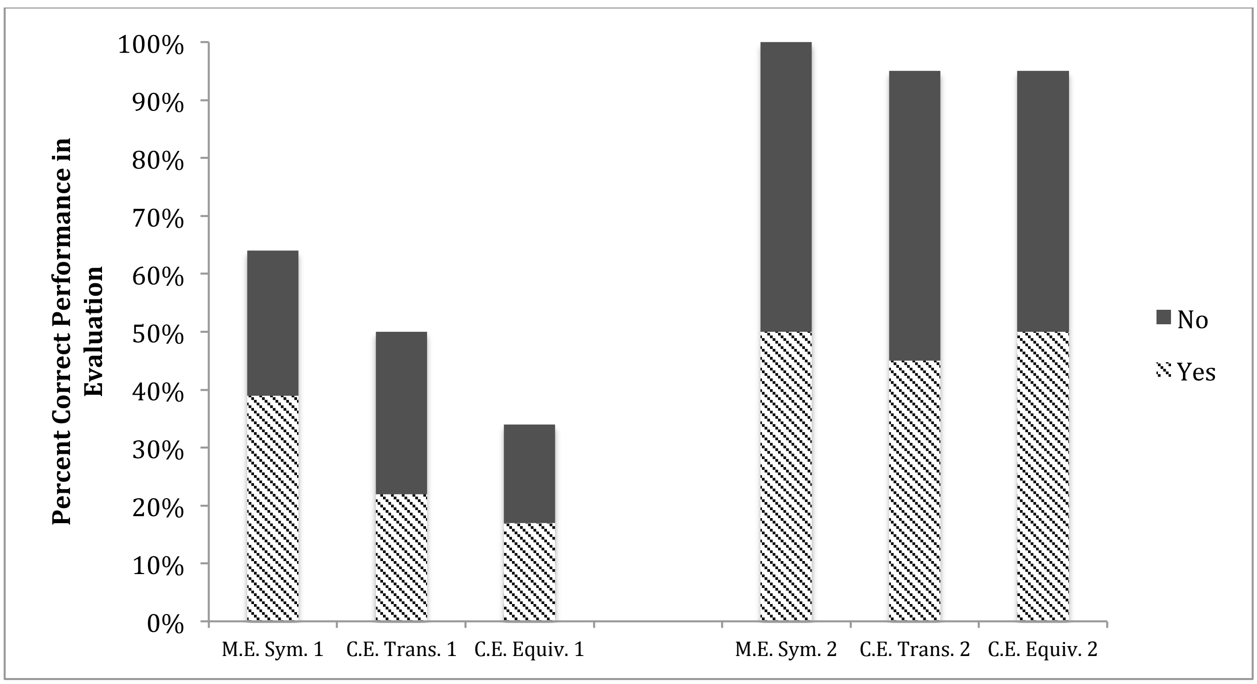

Figure 10 **Percent correct performance observed in evaluation conditions for participant 4, experiment 2**

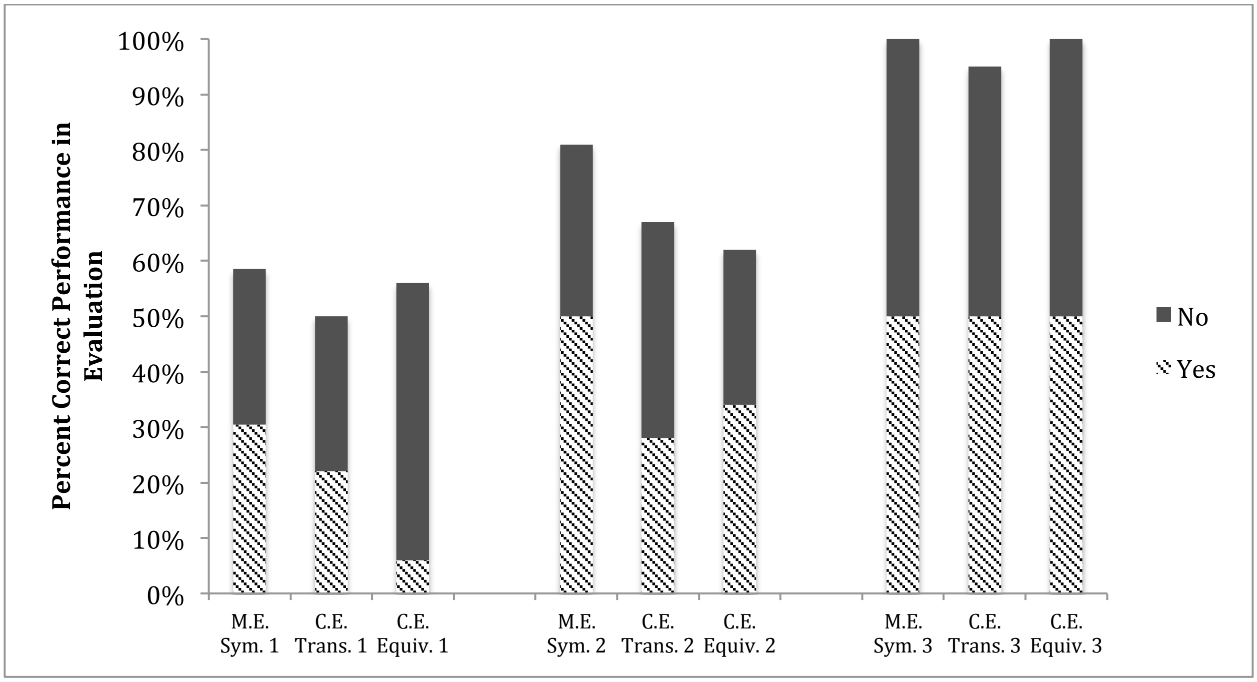

Figure 11 **Percent correct performance observed in evaluation conditions for participant 5, experiment 2**

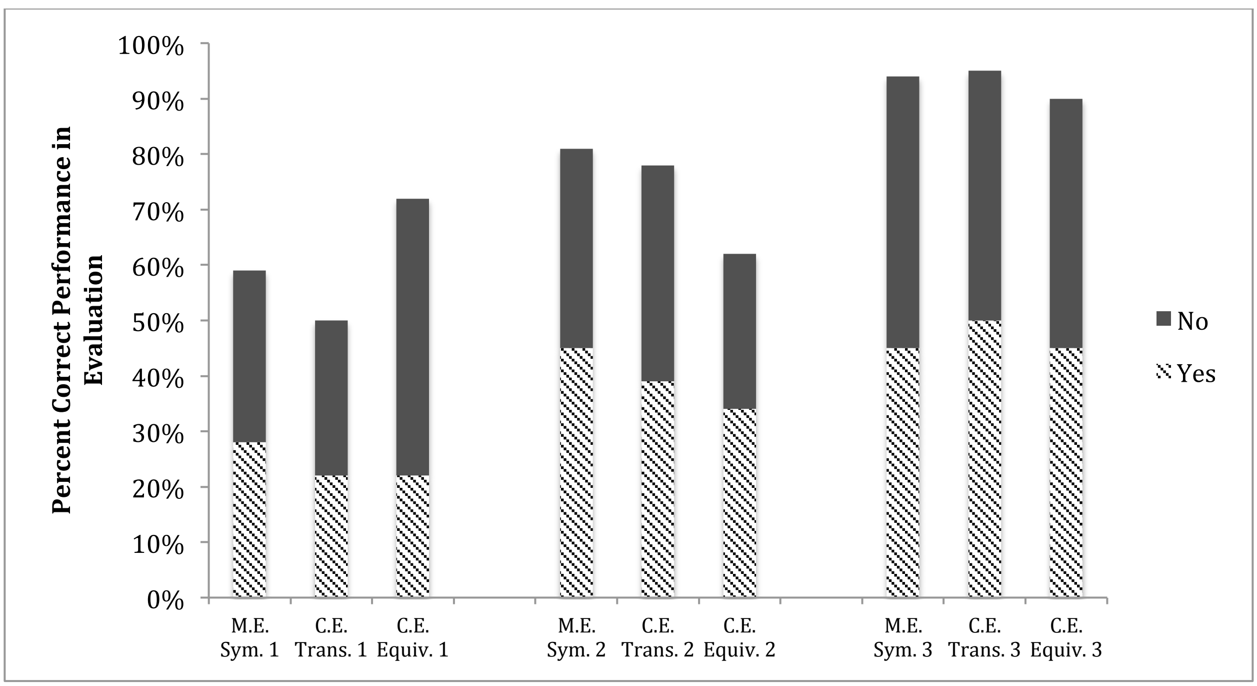

Figure 12 **Percent correct performance observed in evaluation conditions for participant 6, experiment 2**

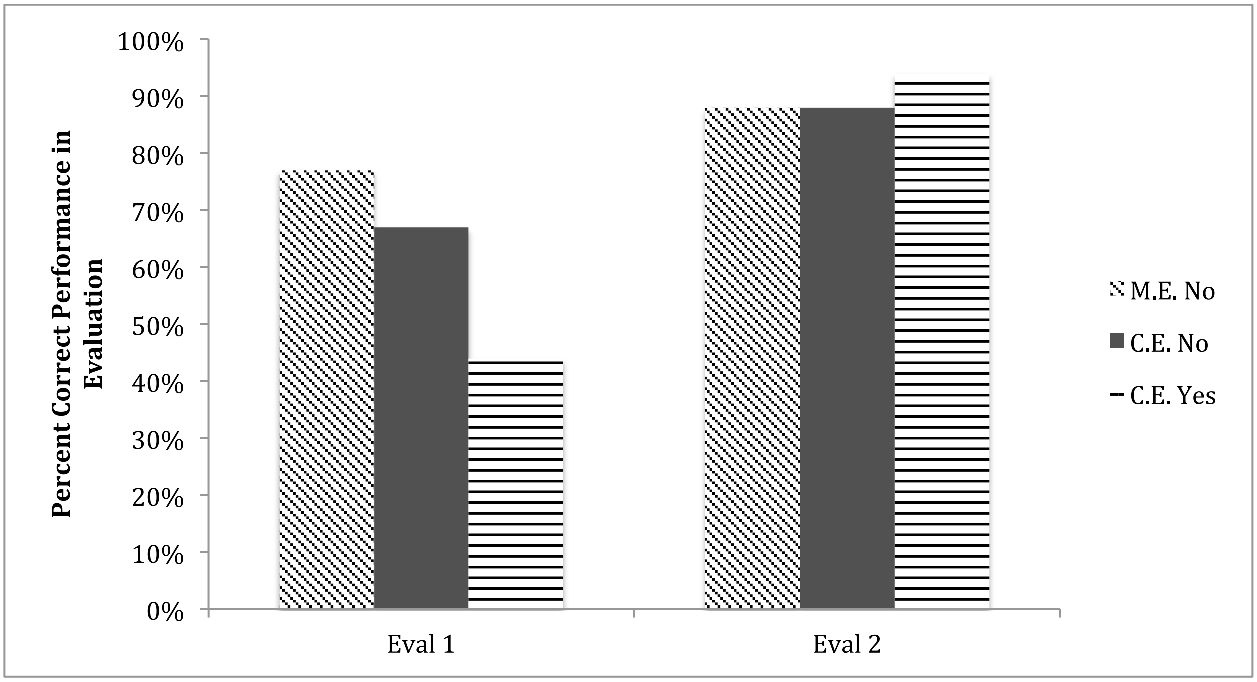

Figure 13 **Percent correct performance observed in evaluation conditions for participant 1, experiment 3**

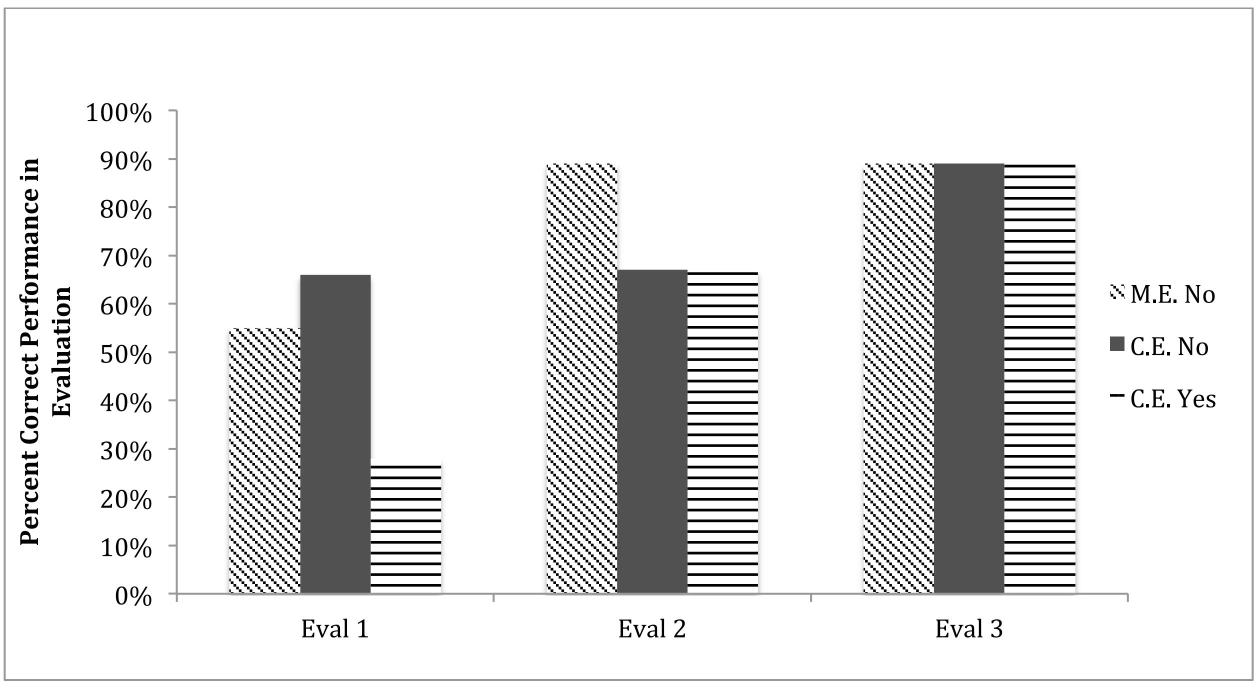

Figure 14 **Percent correct performance observed in evaluation conditions for participant 2, experiment 3**

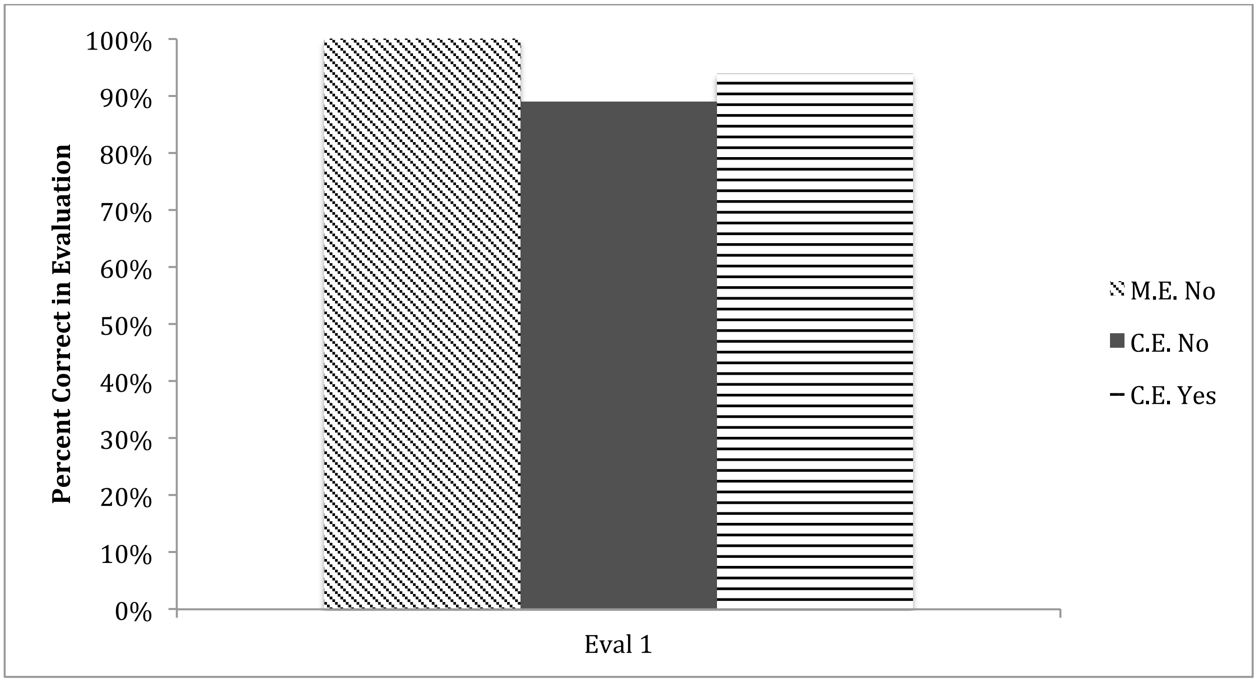

Figure 15 **Percent correct performance observed in evaluation conditions for participant 3, experiment 3**

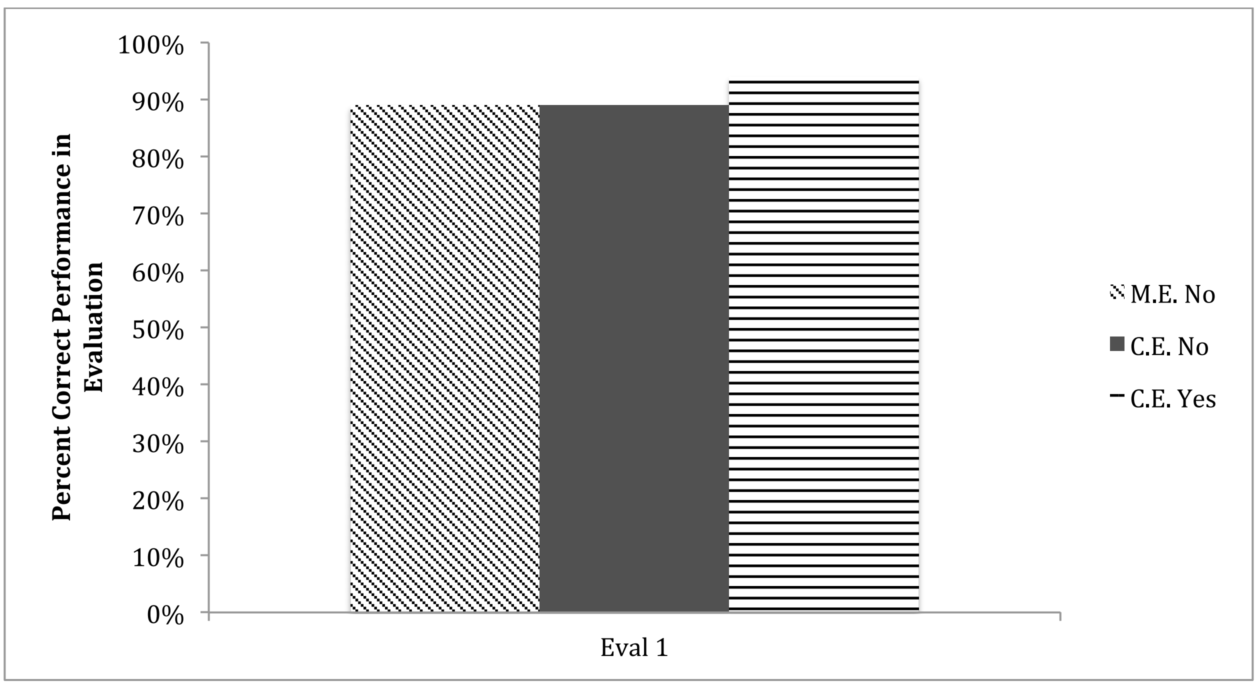

Figure 16 **Percent correct performance observed in evaluation conditions for participant 4, experiment 3**

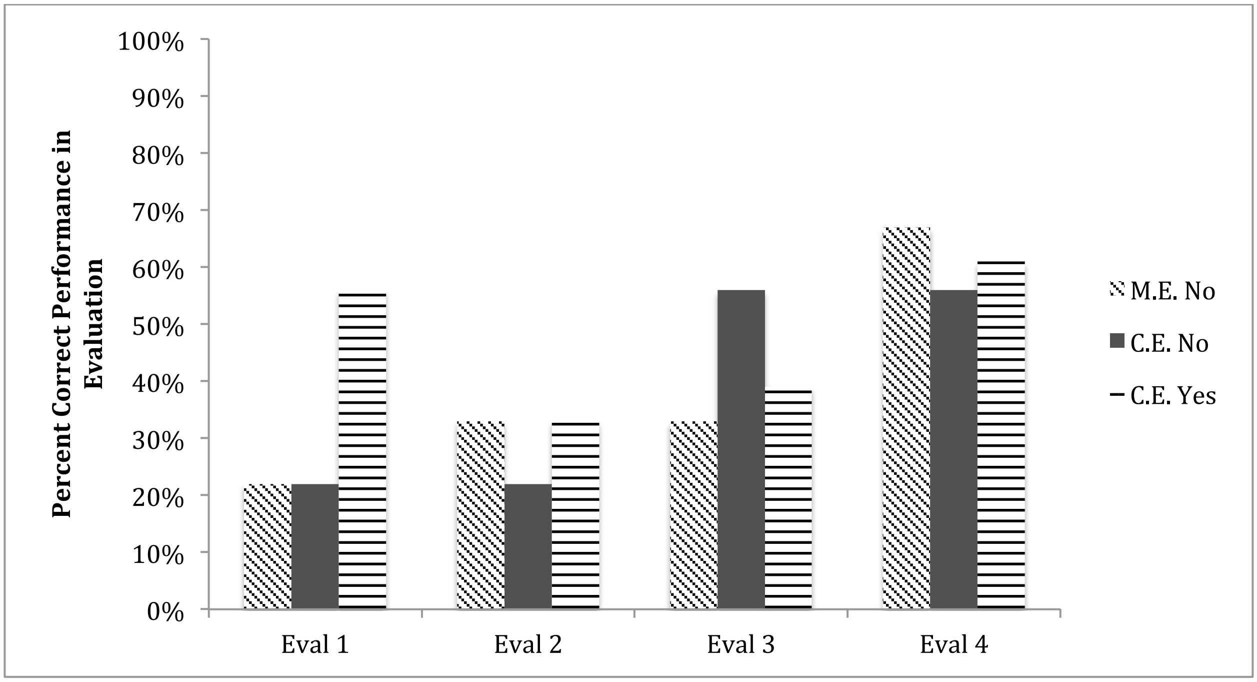

Figure 17 **Percent correct performance observed in evaluation conditions for participant 5, experiment 3**

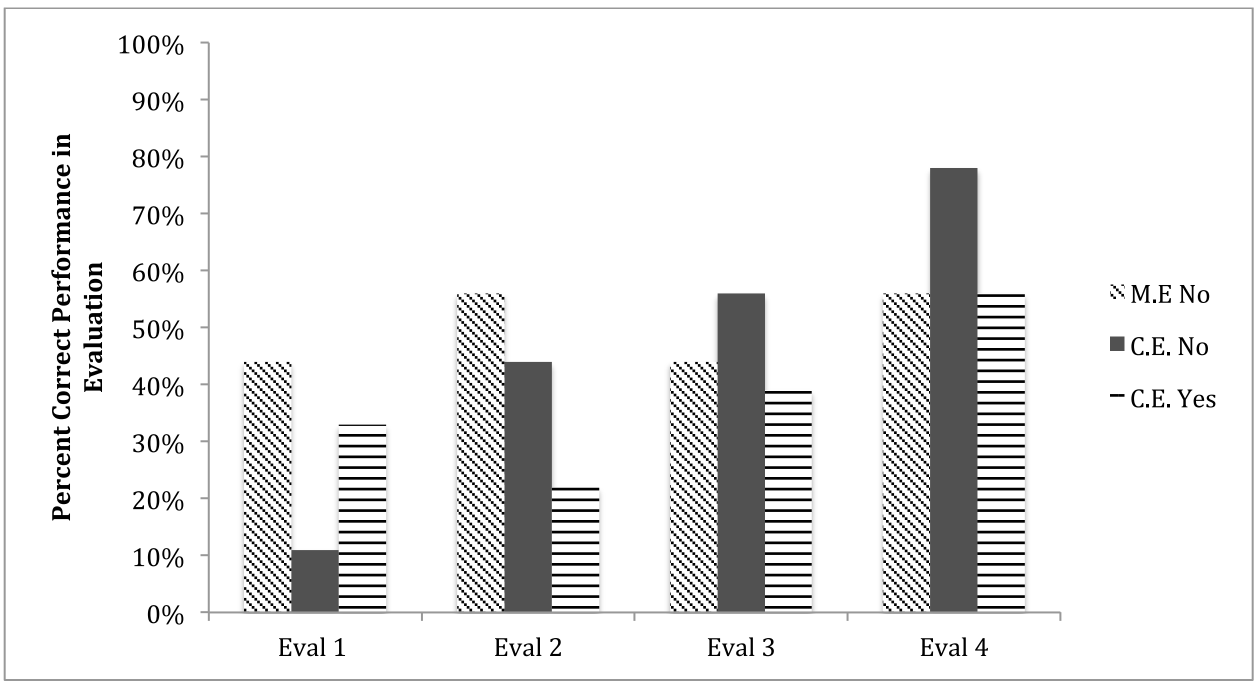

Figure 18 **Percent correct performance observed in evaluation conditions for participant 6, experiment 3**

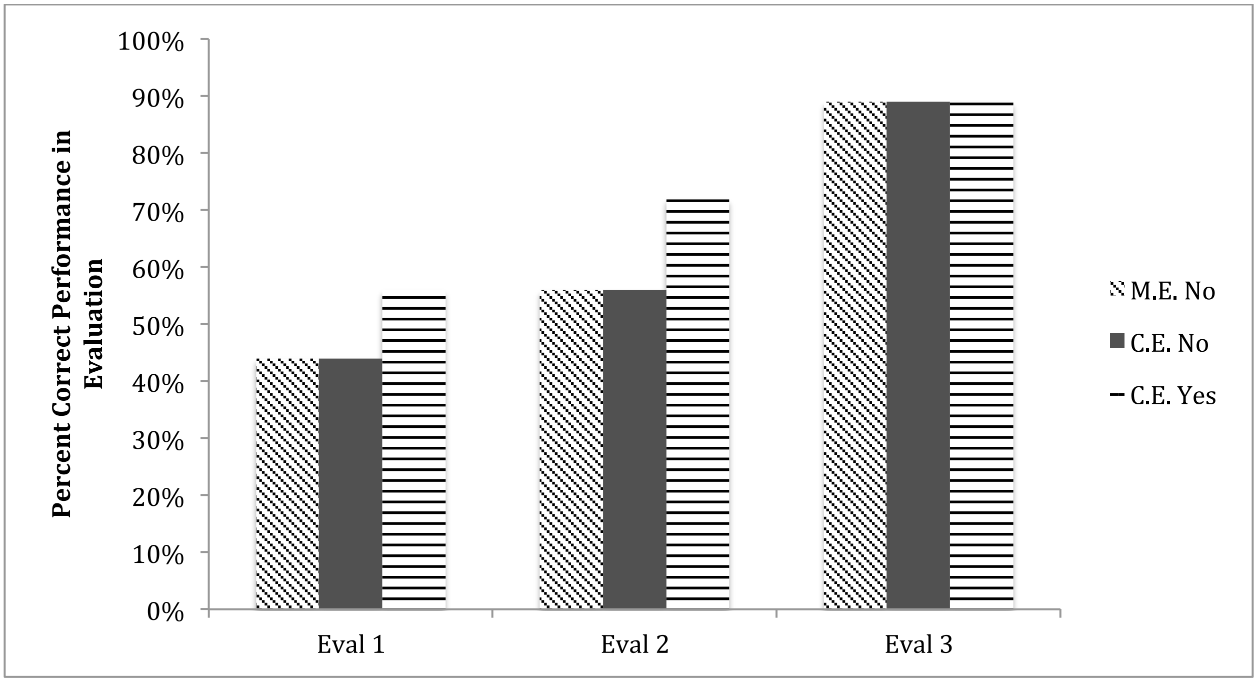

Figure 19 **Percent correct performance observed in evaluation conditions for participant 7, experiment 3**

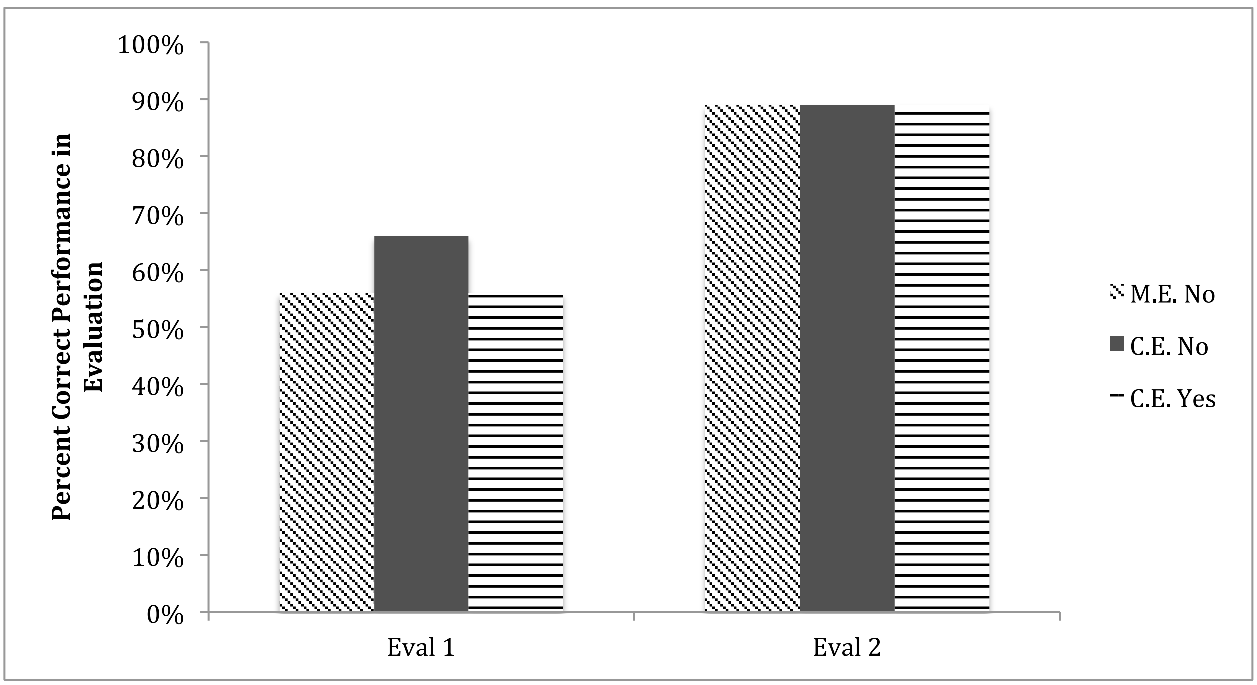

Figure 20 **Percent correct performance observed in evaluation conditions for participant 8, experiment 3**

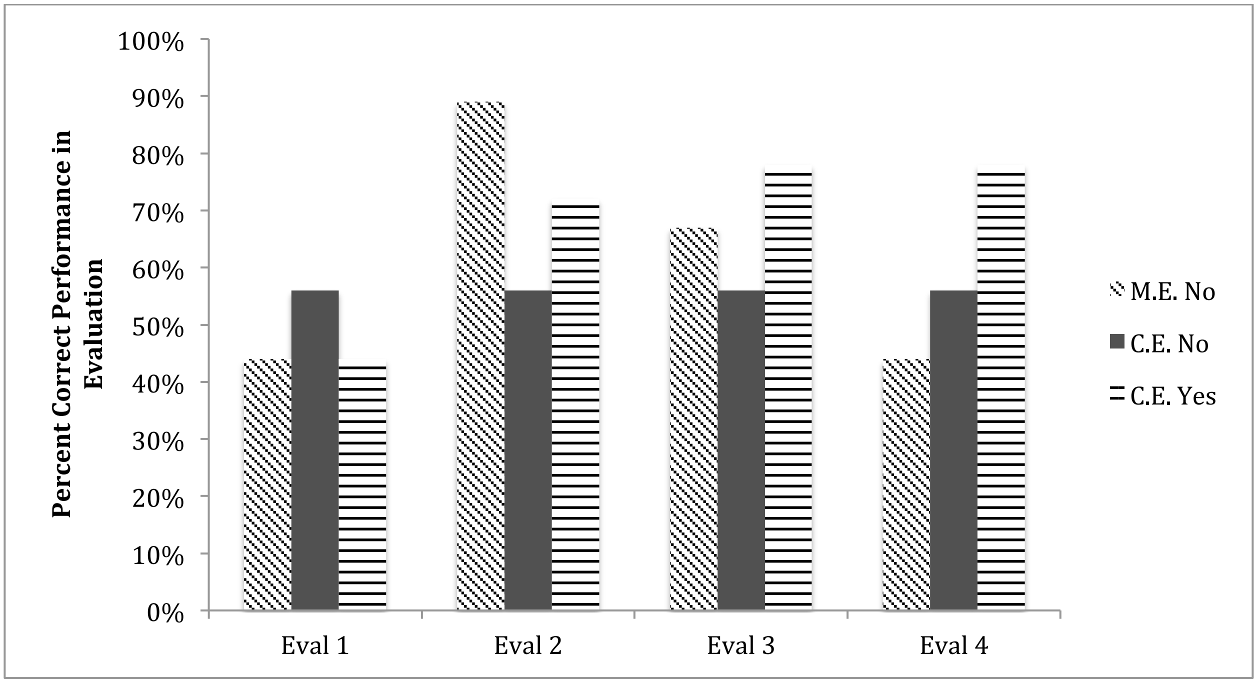

Figure 21 **Percent correct performance observed in evaluation conditions for participant 9, experiment 3**

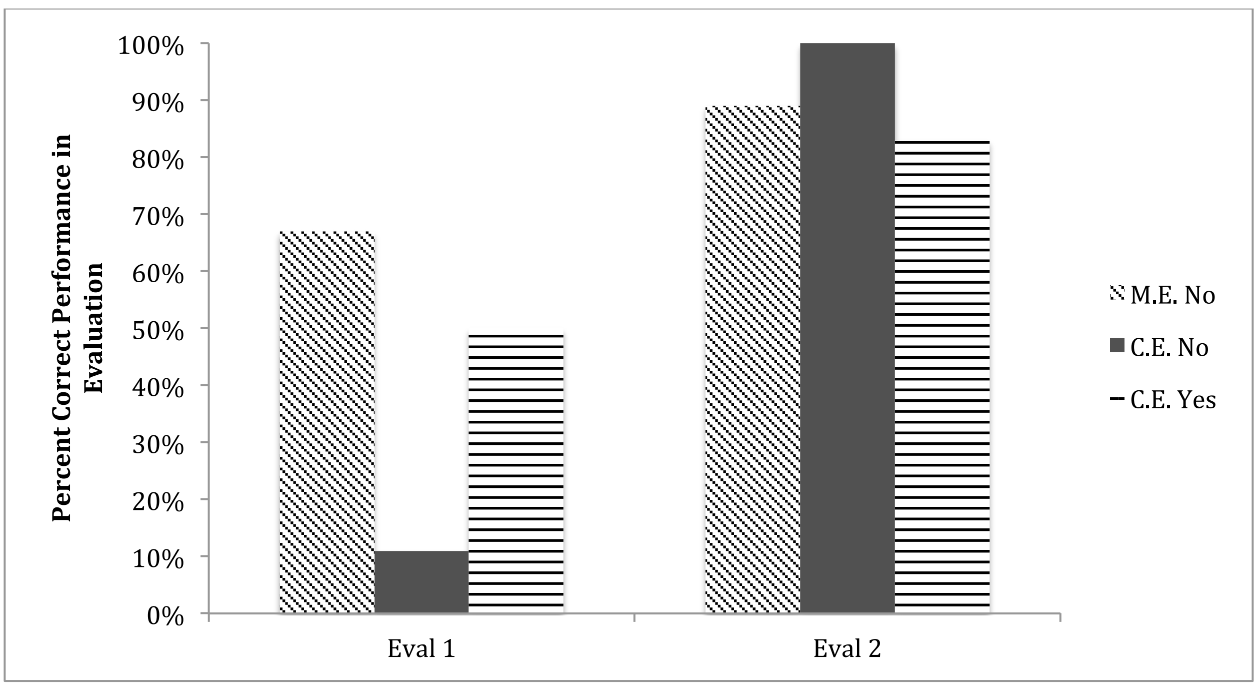

Figure 22 **Percent correct performance observed in evaluation conditions for participant 10, experiment3**