Exposure to Progressive Muscle Relaxation leads to Enhanced Performance on Derived Relational Responding Tasks.

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SUGGESTED RUNNING HEAD: PMR and Derived Relational Responding

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**Abstract**

Previous research has demonstrated that sleep significantly enhances the emergence of 2- but not 1-node derived relations following a 12-hour period. The present study investigated whether a highly truncated relaxation intervention in the form of an 11-minute Progressive Muscle Relaxation (PMR) exercise would effect a similar enhancement in derived relational responding. Thirty-five participants were exposed to matching-to-sample training to establish stable baseline relations, from which 1- and 2-node equivalence relations were predicted. Participants were then randomly assigned to either a PMR group or one of two control groups; Simple or Conditional Discrimination task, followed by an equivalence test. Exposure to PMR resulted in significantly more accurate responses for both 1- and 2-node derived relations. The immediate and significant effects of the brief intervention on derived relational responding support the view that relaxation improves cognitive performance as indexed by the emergence of derived equivalence responding.

*Keywords*: Derived relational responding, relaxation, meditation, cognition, stimulus equivalence.

Interest in the beneficial effects of meditation training in a wide variety of psychological contexts has grown rapidly in recent years (Brown, Ryan, & Cresswell, 2007; Carlson & Hoyle, 1993; Feldman, Greeson, & Senville, 2010). Although there are a variety of meditation techniques such as, Transcendental Meditation (TM; Kabat-Zinn, 1994) and Progressive Muscle Relaxation (PMR; Jacobson, 1938), the outcome is generally a relaxed physiological state and a passive accepting frame of mind, in other words, a ‘relaxation response’ (Benson, 1975). According to Benson (1975), this relaxation response is an inducible physiological state of quietude which has the purported effect of enhancing a persons’ capacity to attend more precisely to environmental events. During relaxation training meditators are taught to acknowledge the distracting discursive thoughts that inevitably intrude, and non-judgmentally return their attention back to their breathing (Wallace, 2006). With increased experience meditators report fewer intrusions of irrelevant thought (Feldman et al., 2010; Kabat-Zinn, 1994). Relaxation is the antithesis of a general arousal or stress response (Benson et al., 2000) and is essentially a wakeful hypometabolic state (Wallace, Benson, & Wilson, 1971).

Irrespective of the type of relaxation technique employed the effects are quite similar in terms of their stress reducing properties (Brown et al., 2007; Rausch, Gaumling, & Auerbach, 2006; Travis et al., 2009) and benefits to mood and cognition (Miller, Fletcher, & Kabat-Zinn, 1995; Nava, Landau, Brody, Linder, & Schächinger, 2004). Indeed, in the cognitive domain relaxation training has resulted in significant improvements in attention (Grosschalk & Greg, 1996), visuospatial processing (Kozhevnikov, Louchakova, Josipovic, & Motes, 2009), and memory capacity (Subramanya & Telles, 2009). Furthermore, relaxation techniques have facilitated significant increases in multiple measures of intelligence (Cranson et al., 1991), greater flexibility in concept learning (Dillbeck, 1982; Grosschalk & Greg, 1996), along with improved problem solving ability across age groups from young children to the elderly (Krampen, 1997).

The majority of the studies demonstrating improvement in cognitive performance (e.g., Cahn & Polich, 2006) involve extensive, long-term relaxation training. However, there is a growing body of evidence in support of brief relaxation training. For example, Tang et al. (2007) reported that exposure to five days of 20-minute Integrative Body Mind Training sessions improved both cognition, as indexed by increased scores on the Attention Network Test. More recently, Zeidan, Johnson, Diamond, David, and Goolkasian (2010) reported improvements in verbal fluency, visual coding, and working memory following four days of brief 20-minute meditation training. Moreover, some studies have shown that considerable cognitive benefits can be achieved following a single relaxation session. Indeed, Nava et al. (2004) demonstrated enhanced long term memory retention performance following a single 12-minute relaxation session while Hudetz, Hudetz, and Klayman (2000) showed enhanced working memory performance following 10 minutes of guided imagery.

There is some debate regarding the unique contributions of relaxation on cognitive processes such as attention, perception, memory, and concept formation (Ellenbogen, Hu, Payne, Titone, & Walker, 2007; Ellenbogen, Hulbert, Jiang, & Stickgold, 2009; Krampen, 1997, 2010). The current study examined the effects of brief relaxation training on cognitive performance, by use of a task of great interest to experimental analysts of behavior: the formation of derived equivalence relations (Sidman, 1994). This particular task is of interest because many behavioral psychologists take the position that the derivation of relations between stimuli underpins many aspects of complex human language and cognition (e.g., Fields & Verhave, 1987; Hayes, Barnes-Holmes, & Roche, 2001; Sidman, 1994, 2000).

Derived relational responding refers to the emergence of class-consistent responding to untrained and stimulus-stimulus relations. Typically, in a study on stimulus equivalence, a series of conditional discriminations involving arbitrary, physically dissimilar stimuli are presented in a match-to-sample (MTS) format. For instance, in the presence of sample stimulus A, selecting comparison B is reinforced (i.e., A-B) and on other trials selecting comparison C in the presence of sample A is reinforced (i.e., A-C). Following this training history, if the relations B-A, C-A (i.e., symmetry), B-C and C-B (i.e., combined symmetry and transitivity) emerge in the absence of any further training, the stimuli are said to have formed equivalence relations (Sidman, 1994) or to participate in a relational frame of co-ordination (Hayes et al., 2001).

Much recent research on stimulus equivalence relations has focused on how the formation of equivalence classes may be enhanced by the inclusion of meaningful stimuli in the trained baseline relations (e.g., Fields, Arntzen, Nartey, & Eilifsen, 2012; Arntzen, Nartey, & Fields, 2015) or manipulation of the training structures designed to establish such classes (e.g., Arntzen, Grondahl, & Eilifsen, 2010; Grisante et al., 2013). While that strand of research focuses on enhancing derived relational responding by manipulation of stimulus content and training structure, the present study aims to enhance derived relational responding by manipulation of context in which such stimulus relations are established and emerge.

The present research also builds on the work of Ellenbogen et al. (2007), who found that engaging in 12 hours of sleep post-training increased participants’ ability to derive complex transitively inferred relations between stimuli separated by two nodes from each other in a series of premise pairs (e.g., derived A>D, given A>B, B>C, C>D, D>E), but not stimuli separated by one node only (e.g., A>C). Thus, if brief relaxation training can be shown to improve cognitive performance, operationalized here as derived relational responding, we might conclude that it is the relaxation component of sleep that most likely contributes to the cognitive improvements widely observed following a period of sleep.

In the present study participants were randomly assigned to three groups, exposed to MTS training, and subsequently exposed to one of three different experimental conditions. Conditions 1 and 2 comprised a Simple and Conditional Discrimination task, respectively, which were designed to inhibit deep relaxation and prevent rehearsal of trained baseline relations, thus, acting as control interventions. Condition 3 involved exposure to an audio guided 11-minute PMR intervention. Following the interventions, a MTS testing task probed for the emergence of equivalence relations. Based on previous research (Tang et al., 2007; Zeidan et al., 2010) exposure to a brief PMR exercise should enhance cognitive performance as measured by the immediate emergence of 1- and 2-node derived stimulus relations, relative to two non-relaxation conditions. Moreover, the design of the current study allowed for a direct comparison of the effects of the intervention on 1- and 2-node derived relational responding (Ellenbogen et al., 2007).

**Method**

**Participants**

Fifty participants were recruited via personal contacts and advertisements offering a potential prize of 30 euro placed on campus notice-boards at the National University of Ireland, Maynooth. Participants comprised both undergraduate students and university graduates engaged in full-time employment. Overall, participants in each condition were roughly matched for age, educational status and socio-economic background and had normal or corrected-to-normal vision. No participant had prior knowledge or experience with stimulus equivalence research.

Fifteen participants were eliminated from the study due to their performance on the MTS training or the baseline test phase. Of the 35 remaining participants, 18 were female and 17 were male, with an age range of 18-49 years (*M* = 24.09; *SD* = 8.29). Informed consent was obtained from all participants, with all procedures approved according to the National University of Ireland Maynooth Research Ethics policy. Participants were made fully aware that they could withdraw from the study at any stage and received a full debriefing session upon completion of their participation.

**Apparatus/Materials**

Participants completed the experiment individually, seated at a table facing an Apple e-Mac© with an 800 x 600 pixel screen and a mouse. Stimulus presentation and response recording were controlled by the software application PsyScope version B55 (Cohen, Mac Whiney, Flatt, & Provost, 1993). Stimuli and feedback were displayed on screen using Times New Roman 24-point font on a white background. Stimuli were displayed in black and feedback in red characters. Eight nonsense syllables, CUG, PAF, VEK, JOM, ZID, KER, LEF and MAU were employed as stimuli during equivalence training and testing, labelled A1, B1, C1, D1, A2, B2, C2 and D2 for clarity, although participants were not exposed to the alphanumeric designations. One Red and one Blue solid circle, diameter 3 cm, functioned as visual discriminative stimuli during the Simple Discrimination task. Eight further nonsense syllables, LIR, FIM, RET, KAV, GIM, JOR, BOC, LUT, labelled A3, B3, C3, D3, A4, B4, C4 and D4 respectively, were employed as stimuli during the Conditional Discrimination task which consisted of further conditional discrimination trials similar in format to those employed during Phase 1 baseline training.

All interventions were delivered via the computer and the use of a pair of standard lightweight headphones. During the relaxation training a PMR instruction set was delivered in audio via the headphones while a solid green background was displayed on screen (see Appendix).

**Procedure**

The study comprised five phases. Participants were randomly assigned to one of three experimental conditions and completed a consent form. The participants sat facing a computer screen with a mouse positioned at their right-hand side and read the instructions displayed on screen. The experimenter then left the room.

**Phase 1: Baseline Acquisition***.*

Instructions on how to engage with the MTS tasks were displayed on screen at the beginning of Phase 1 and remained on screen until the participant acknowledged them by pressing the space bar as instructed.

On all trials the sample stimulus appeared in the centre top-half of the screen and the two comparison stimuli to the left and right below the sample at the bottom edge of the screen after a 1 s delay. There was no observing response during this delay in the presentation of the two comparison stimuli following the appearance of the sample stimulus. The left and right positions of comparison stimuli were counterbalanced across trials. Both sample and comparison stimuli remained on screen until the participant clicked on a comparison stimulus using the mouse. While baseline relations were being established a correct response was followed by the presentation of the word “Correct” on screen and accompanied by a beep while an incorrect response was followed with the screen presentation of the word “Wrong” with no accompanying sound. The feedback message (“Correct” or “Wrong”) was displayed in the middle of the screen for 1.5 s followed by an inter-trial interval of 1 s.

The six baseline relations for the two four-member equivalence relations were trained during MTS based trials. Participants were trained to match A1-*B1*/B2, B1-*C1*/C2, C1-*D1*/D2, A2-*B2*/B1, B2-*C2*/C1 and C2-*D2*/D1 where italics indicate the correct response (i.e., a serial training protocol).The six trial types were presented in blocks containing two trial types repeated five times in a quasi-random order. Nine consecutively correct responses in a block of 10 trials were required to complete a block satisfactorily. Participants were recycled through training blocks until they made ≥ 9/10 responses within a block. On reaching this criterion the next pair of randomly selected trial types was presented.

**Phase 2: Baseline Integration training**.

The final training block contained a combination of all six trial types in a quasi-random order with each trial type repeated five times for a total of 30 trials in a block. The criterion for completing the final training block was ≥ 29/30 (96.7%) correct responses. Participants who made more than one incorrect response in a block were re-exposed to the block until the mastery criterion was achieved or for 30 minutes, which ever was reached first. If a participant did not achieve the mastery criterion within this timeframe, they were excused from the experiment and their data were not included in subsequent analyses. These participants were fully debriefed and thanked for their participation. When all baseline relations were acquired, the participants were presented with on-screen instructions that informed them to contact the experimenter in order to begin the next phase of the experiment.

**Phase 3: Baseline Maintenance (MTS) Test***.*

The Baseline Integration phase was followed by a test block in which all of the baseline relations for all potential classes (i.e., A1-B1, B1-C1, C1-D1, A2-B2, B2-C2, and C2-D2) were administered in the absence of informative feedback. Instructions, sample stimuli and comparisons were presented, and responses recorded, in the same manner as in Phase 2, but no informative feedback was presented. Participants who failed a testing-block (i.e., <100% correct responses) were re-exposed to a Phase 2 (Baseline Integration) 30-trial training block until criterion was met (i.e., ≥ 29/30 correct responses). They were then re-exposed to the Phase 3 test-block until it was passed successfully (i.e., 30/30 correct responses) or until a further thirty minute time limit was reached. Participants who did not achieve mastery were deemed to have failed the task, did not proceed to the subsequent phases and their data was not included in the subsequent analyses.

**Phase 4: Interventions***.*

Upon successful completion of the baseline test (Phase 3), the participants were randomly assigned to the PMR relaxation intervention, or one of the two non-relaxation interventions (the Simple Discrimination task or the Conditional Discrimination task). All three interventions were 11 minutes in duration.

***PMR (Relaxation) Condition****.*

Participants listened to a recorded Progressive Muscle Relaxation (PMR) instruction set based on Jacobson’s (1938) principles (see Appendix). Instructions were displayed on screen informing participants how to proceed. A key press or mouse click removed the instructions from the screen, changed the screen to green and commenced the PMR audio clip.

***Non-relaxation Condition 1: Simple Discrimination Task****.*

Instructions were presented to participants on screen that this task consisted of the presentation of a series of blue and red circles in a random order (4cm diameter approx.), and that they should click only on the red circles. Their objective was to make as many correct responses as possible. Audio response feedback was relayed to participants via the headphones. Stimuli and their on-screen position were quasi-randomly selected across 8 locations. Target stimuli (e.g., a red circle) remained on screen until participants made a correct response. In the absence of a response after 3s the target stimulus was accompanied by the printed instruction “Click On The Red Circle” displayed in the centre of the screen for a duration of 3s. This feedback was presented only once for each target stimulus. A correct response removed the red circle and the instruction stimuli from the screen and initiated the next trial. The second stimulus type (a blue circle) was displayed on screen for 3s, after which the next trial was presented. Responses during this stimulus presentation were punished with verbal feedback. That is, a response to the blue circle led to the presentation of the printed instruction “Don’t Click on Blue Circles” in the centre of the screen. Feedback was accompanied by a click sound relayed via the headphones. After 3s the feedback message was removed from the computer screen and the next trial was presented. There was no inter-trial interval. All trials were presented in a quasi-random order such that there were no more than two successive exposures to either trial type. Performance data was not collected for this condition as no mastery criterion was set. Rather, it was designed to engage participants in a simple discrimination task for a period of 11 minutes.

***Non-relaxation Condition 2: Conditional Discrimination Task****.*

The Conditional Discrimination task replicated the training delivered in Phase 1 with the exception that it employed novel stimuli unrelated to the rest of the experiment (A3-B3; B3-C3; C3-D3; A4-B4; B4-C4; C4-D4). On-screen instructions mirrored those used in Phase 1. In other words, participants were trained to match the following six stimulus pairs A3-*B3*/B4, B3-*C3*/C4, C3-*D3*/D4, A4-*B4*/B3, B4-*C4*/C3, and C4-*D4*/D3 (italics indicate the correct response) in blocks with two trial types repeated five times each. As in the Simple Discrimination Condition above, performance data was not collected for this Conditional Discrimination Condition as it was merely designed to engage participants in a cognitively demanding task for a period of 11 minutes. Thus, no matter how successfully or poorly a participant performed in the conditional discrimination task, the training program terminated once 11 minutes had elapsed.

**Phase 5: Equivalence Test***.*

On-screen instructions informed participants how to respond on trials to be presented in this, the final phase of the experiment. These trials probed for the emergence of equivalence relations. Specifically, it probed for the 1-node derived relations C1-A1 and C2-A2, as well as the 2-node derived relations D1-A1 and D2-A2. The test block consisted of 40 trials (i.e., each of the 4 trial types presented 10 times each in a quasi-random order) and was administered only once, regardless of performance. Comparisons were presented in the same manner as in Phase 1 training, but no feedback was provided for the selections of either comparison stimulus in any trial. Thus, this probe block did not include trials that assessed the maintenance of the baseline relations, or other derived relations probes that assessed the emergence of symmetrical relations or transitive relations. The total number of correct responses recorded for each participant constituted the main dependent measure used to assess the impact of each intervention on the emergence of derived relational responding.

**Results**

Of the 50 participants, 15 failed to acquire or maintain the baseline relations in Phases 1 - 3. Of the remaining 35 participants that maintained the baseline relations, 12 participants were assigned to the Simple Discrimination, and the PMR conditions, and 11 were assigned to the Conditional Discrimination Condition. The performances of these participants were analysed in all phases of the experiment.

**Baseline acquisition, integration, and maintenance**

An average of 163.7 trials was needed to acquire the baseline relations. Inspection of the Raw data showed large variations in the number of training trials required to reach criterion- by participants within and across- the groups (see Table 1). A Kruskal-Wallis Test found no significant differences in trial to baseline acquisition requirements χ2 (2, 35) = .31, *p* = .857 across conditions. Thus, differences in acquisition could not account for any differences observed in performance on the subsequent equivalence tests.

**Baseline Maintenance**

Thirty-five participants reached criterion (100% correct) on their one and only exposure to Phase 2 (see Table 1).

**Equivalence Test**

Each participant completed one test block comprising 40 trials (20 trial probes for one-node derived relations and 20 trial probes for two-node derived relations). Table 1 shows the number of correct responses recorded for each participant during the stimulus equivalence test phase subsequent to exposure to one of the three intervention conditions. Response accuracies were also analysed separately for 1-node (C-A) and 2-node derived (D-A) relations. The data for total, 1-node and 2-node derived relational response accuracy were normally distributed for all three conditions Simple Discrimination, Conditional Discrimination, and PMR.

Traditionally a criterion of 90% accuracy is used to define the emergence of stimulus equivalence, whereas in the current study a criterion of 100% was applied. When a criterion of 90% accuracy (i.e., 36 correct out of 40) is employed to define a “pass” during derived relational responding testing in the current study, 4/12 (33.33%) participants in the PMR condition demonstrated transitivity. However, none of the participants in the other two conditions reached this criterion. The effect of the relaxation intervention on pass rates at 90% accuracy is more pronounced when different nodal distances are considered separately. During the 1-node transitive testing trials, 5/12 participants (41.67%) in the PMR condition passed derived relational responding testing, whereas only 1/11 (9%) and 0/11 (0%) participants passed in the Conditional and Simple Discrimination conditions, respectively. The effect was even more distinct at a distance of 2-nodes, with 6/12 participants (50%) in the PMR condition reaching the 90% pass criterion. Only 1/12 (8%) participants reached this criterion in the Simple Discrimination Condition and none in the Conditional Discrimination Condition.

Of the 35 participants, those in the PMR intervention scored significantly higher mean response accuracies for total (*M* = 27.83), 1-node (*M* = 13.50), and 2-node (*M* = 15.17) probe response accuracies than either the Simple or Conditional Discrimination interventions, in line with experimental predictions. The mean response accuracy of participants in the Conditional Discrimination intervention for total (*M* = 19.08), 1-node (*M* = 8.42) and 2-node (*M* = 10.67) probes were the lowest of the three conditions. The mean response accuracy scores for participants in the Simple Discrimination intervention for total (*M* = 17.64), 1-node (*M* = 7.00) and 2-node (*M* = 10.36) probes were marginally higher than, but not significantly different from, the response accuracy scores observed in the Conditional Discrimination Condition, and significantly lower than those observed for the PMR Condition.

Closer inspection of the data also revealed that the highest response accuracy was recorded in the PMR condition. One participant (P15) achieved maximum response accuracy (i.e. 20 out of 20 correct) for both 1- and 2-node derived relational probes, with only one other participant (P26) recording maximum accuracy for two-node probes. Overall, the results suggest that the PMR intervention had an effect on participants’ subsequent performance in the derived relational responding test phase.

A one-way between groups analysis of variance (ANOVA) was conducted to explore the impact of intervention type (Simple Discrimination, Conditional Discrimination, and PMR) on derived relational responding. Levene’s Test of Equality of Variances violated the assumption of homogeneity of variances *F*(2, 32) = 10.637, *p* < .001, therefore Welch’s statistic is reported. There was a statistically significant difference among the groups in derived relational responding, *F* (2, 32) = 5.26, *p* = .015, with a large effect size (ƞ*2*= .33; Cohen, 1988). Tukey HSD post-hoc comparisons indicated that the mean score for the PMR group (*M* = 27.83, *SD* = 9.62) was significantly greater than both the Simple Discrimination task group (*M* = 19.08, *SD* = 4.30), and the Conditional Discrimination task group (*M* = 17.64, *SD* = 4.65). The Simple and Conditional Discrimination task groups did not significantly differ from each other.

**1- and 2-node probes**

The derived relational responding accuracy of participants was separated for 1-node and 2-node probes. Preliminary statistics showed no violation of the assumptions of normality with Kolmogorov-Smirnov significance value of .2 for groups 1 and 2 for both one and two nodal distances, and a value for group 3 of .16 for one nodal distance and .10 for two-nodal distances. Levene’s statistic demonstrated no violation of the assumption of homogeneity of variances, *F*(2, 32) = 1.65, *p* = .21 for 1-node distance and *F*(2, 32) = 2.12, *p* = .14 for 2-node distance.

A one-way between-groups ANOVA revealed a statistically significant difference among the groups at the p < .05 level for a distance of 1-node: *F*(2, 22) = 5.861, *p* = .01, with a large effect size (ƞ*2*= .27; Cohen, 1988). Tukey HSD post-hoc comparisons indicated that the mean score for the PMR Condition (*M* = 13.50, *SD* = 5.54) was significantly higher than the Simple Discrimination Condition (*M* = 8.42, *SD* = 3.80) and the Conditional Discrimination Condition (*M* = 7.00, *SD* = 5.00). The Simple and Conditional Discrimination task conditions did not differ significantly from one another. Thus, the PMR relaxation intervention resulted in significantly more accurate responding rates for 1-node probe derived relations than either the Simple or Conditional discrimination tasks.

For a distance of 2-nodes a one-way between-groups ANOVA also showed a large statistically significant difference between the groups: *F*(2, 32) = 4.26, *p* = .02, ƞ*2* = .21. Tukey HSD post-hoc comparison tests found that the mean score for the PMR group (*M* = 15.17, *SD* = 5.15) was significantly higher than the mean score for both the Simple Discrimination (*M* = 10.67, *SD* = 4.94) and Conditional Discrimination groups (*M* = 10.36, *SD* = 2.84). Analyses of the mean derived relational response fluency for a distance of 2-nodes found that the PMR intervention again resulted in significantly more accurate response rates than either of the other two non-relaxation interventions.

**Discussion**

A brief relaxation intervention significantly increased cognitive performance operationalized as the emergence of derived relational responding in the context of equivalence class formation. These findings are consistent with the literature reporting enhancements to other forms of cognitive function following extensive or relatively short bouts of meditation training (Krampen, 1997; Rausch et al., 2006; Zeidan et al., 2010).

The current study complements these findings by showing that a very short term intervention that induced relaxation enhanced the immediate emergence of 1- and 2-node equivalence relations, which is a core behavioral process that documents the formation of equivalence classes, thought by many to underlie human cognition (Fields & Verhave, 1987; Hayes et al., 2001; Sidman, 1994, 2000). Since significant improvements in these core processes were observed after a short relaxation intervention, the effects of short or longer regular relaxation training on everyday cognitive functions that depend on mediated learning such as inference, numeracy, literacy, and creativity could be impressive. That is not to suggest that brief relaxation training is as effective as extensive long-term training schedules, the long lasting effects of which are well documented in the literature (Davidson et al., 2003; Lazar et al., 2005). However, the immediate and short term benefits may make relaxation techniques more attractive if they are shown to be effective in the absence of extensive training, thus enhancing the versatility of their employment in a variety of settings including medical, academic and the workplace environment.

The cognitive enhancement following relaxation training was evident for the more simple forms of derived relational responding (1-node probe), in contrast to the cognitive effects observed following sleep in the Ellenbogen et al. (2007) study. In that study sleep did not enhance performance in deriving 1-node relations, following a 12 hour post-learning period containing sleep. Furthermore, no significant differences were observed following a 20-minute post-learning period with or without sleep for both 1- and 2-node derived relations. Those results contrast with the findings of the present study in which significant improvements in performance were observed for both 1- and 2-node derived relations following 11 minutes of PMR. Of course, it is important to acknowledge that there were differences in the training protocols employed across the two studies and the relations were of a different kind (“greater than” relations, as opposed to equivalence relations). There is also a stark contrast between the time frame required to demonstrate significantly improved cognition following relaxation (11 minutes in the current study), and sleep (12 hours) in the Ellenbogen et al. study.

The current pass rates in meeting criteria for equivalence responding may appear low in comparison to other stimulus equivalence studies. However, it must be borne in mind that there was only one exposure to a 40-trial testing block in this study, whereas repeatedly exposing participants to the testing block, even following further baseline relations training, is typically reported in the literature. For this reason, performances should not be compared directly to those reported in other studies in terms of “yield”. In addition, increases in the number of equivalence class members have been shown to decrease responding in accordance with stimulus equivalence (Saunders, Chaney, & Marquis, 2005). This study involved a four-member stimulus class, and in this respect a yield of 50% following a single test block might even be considered high, especially given that the simultaneous protocol employed has been identified as likely the least fruitful of the training protocols (e.g., Arntzen, 2004).

A possible mechanism to help account for superior performance of the PMR group may involve a neural process of retroactive interference occurring in the Discrimination task conditions (e.g., Wixted, 2004). Wixted (2005) argued that much ‘forgetting’ is due to non-specific retroactive interference that acts on memory traces that have not yet had time to consolidate in the hippocampus. Wixted (2004, 2005) proposed that new memories are fragile and need time to consolidate in the hippocampus. During this time the new memories (e.g., trained MTS baseline relations) are particularly vulnerable to interference from any new learning, and importantly, the new stimulus material learned does not need to be similar in content and, therefore, the recently learned relations are not necessarily susceptible to proactive interference. Thus, in the present study the PMR intervention involved no new learning, which may have allowed the recently learned MTS baseline relations the time to consolidate in the hippocampus without being interfered with. In contrast, while the Simple and Conditional Discrimination condition tasks were not cognitively taxing on the participants, and were not similar in content to the earlier MTS training tasks, they still required a degree of discriminating and learning, which placed demands on the limited capacity of the hippocampus. Thus, this new learning task hindered the consolidation of the previously learned MTS baseline relations.

Of course, the forgoing interpretation of the current effects is speculative as it is framed in cognitive and neurobiological terms and still leaves unanswered the question of what behavioral process may be involved in the enhancement of learning by relaxation interventions. It may well be that the effects of baseline relation training requires time to yield derived relations, even if the process at work during that time are of little interest to a behavioral psychologist. The requirement of time for training to take effect does not necessitate the entertainment of mediating processes for a psychologist interested only in the prediction and influence of behavior. For those working from such a perspective we can offer a more parsimonious explanation of the current effects in terms of behavioral competition. Put simply, requiring an organism to engage in an unrelated cognitive task and preventing the non-stimulating passage of time required for training to have its effects (e.g., a conditional discrimination task), may simply constitute behavioral competition, that reduces the efficiency of the training method. This may even apply to routine stimulus equivalence training procedures in which a break is rarely given to participants between training and testing blocks. Alternatively, it could also be that the relaxation intervention may serve as a form of motivating operation (e.g., Laraway, Syncerski, Michael, & Poling, 2003), where we might direct our attention with greater focus to tasks following the reinforcing properties of a non-stimulating passage of time. The current research suggests that at the very least, a short break involving undirected attention (i.e., passive relaxation) between training and testing phases may enhance equivalence yields, but this remains to be tested specifically in future research.

There are number of important empirical questions that could be addressed in future research in this area. Firstly, it is not known whether a higher yield of class consistent responding would have been observed with a delayed testing procedure. Secondly, as this is the first study to examine the effects of a very brief (11-minute) relaxation training on the emergence of derived relational responding, it remains to be seen whether a longer period (i.e., more intensive ‘dosage’) of relaxation training might have a more pronounced positive effect in enhancing the emergence of equivalence relations. Thirdly, to gain a greater degree of control over the efficacy of the relaxation training procedure, and the length of time that participants might be exposed to it in order observe the enhanced class indicative responding effects, monitoring physiological measures of arousal (e.g., galvanic skin responses) over time may be informative indices to incorporate in research designs. Fourthly, while both discrimination conditions, Simple and Conditional, served as control conditions in the present study it is unknown what the effects of an untreated control condition as compared to a relaxation intervention might be and this is something can be addressed in future research. Lastly, the design of the present study is quite simple as the focus was on whether exposure to a brief relaxation intervention could enhance the emergence of 1- and 2-node derived relations. Thus, there are numerous different training protocols that could be employed (e.g., MTS with three comparison stimuli instead of two, a one-to-many MTS design, test blocks with mixed test probe and baseline maintenance trials, the relational evaluation procedure) that may lead to even higher yields in equivalence class responding following a relaxation training intervention than the promising, yet relatively modest, findings reported here. The examination of such procedures in this context might help further elucidate whether exposure to a relaxation intervention actually alters stimulus control.

The results of the present study suggest that brief PMR training enhances cognitive performance on stimulus equivalence tasks. Importantly, the stimulus equivalence task employed here is of great interest to behavior analysts and is of relevance to many forms of complex behavior studied by those of a behavior-analytic persuasion. In effect, this helps to underscore the relevance of the benefits of relaxation, insofar as it appears to enhance performance on a task that many researchers use as paradigm for understanding a wide variety of important cognitive activities.

**Compliance with Ethical Standards**: All procedures in the present study were in accordance with the ethical standards of the National University of Ireland, Maynooth Research Ethics Committee and with the 1964 Helsinki declaration and its later amendments.

**Informed Consent**: Informed consent was obtained from all individual participants in the present study.

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| Table 1.  Participant trial requirements for baseline relation training (Phases 1 & 2), total number of correct responses on the baseline relations test (Phase 3), total number correct during the derived relational responding test (Phase 5), along with a breakdown of the total number of correct responses to 1-node and 2-node derived relations probes during Phase 5. | | | | | | |
|  | | | | | | |
|  | | **Phases 1 - 3** | | **Phase 5** | | |
| Participant | Condition | Training Trials Required | Baseline Test Total Correct | Total No. Correct | 1-Node  No. Correct | 2-Node No. Correct |
| 1 | Simple | 180 | 30 | 20 | 12 | 8 |
| 4 | Simple | 580 | 30 | 15 | 7 | 8 |
| 7 | Simple | 130 | 30 | 20 | 9 | 11 |
| 13 | Simple | 220 | 30 | 18 | 17 | 1 |
| 19 | Simple | 120 | 30 | 19 | 10 | 9 |
| 22 | Simple | 140 | 30 | 29 | 9 | *20* |
| 30 | Simple | 330 | 30 | 14 | 7 | 7 |
| 36 | Simple | 80 | 30 | 17 | 3 | 14 |
| 37 | Simple | 100 | 30 | 18 | 5 | 13 |
| 45 | Simple | 130 | 30 | 14 | 6 | 8 |
| 46 | Simple | 110 | 30 | 21 | 5 | 16 |
| 47 | Simple | 150 | 30 | 24 | 11 | 13 |
| 8 | Cond’nal | 180 | 30 | 12 | 7 | 5 |
| 17 | Cond’nal | 100 | 30 | 29 | *19* | 7 |
| 25 | Cond’nal | 140 | 30 | 21 | 8 | 13 |
| 28 | Cond’nal | 100 | 30 | 16 | 2 | 14 |
| 33 | Cond’nal | 210 | 30 | 20 | 10 | 10 |
| 39 | Cond’nal | 330 | 30 | 19 | 11 | 8 |
| 41 | Cond’nal | 120 | 30 | 14 | 3 | 11 |
| 43 | Cond’nal | 120 | 30 | 15 | 6 | 9 |
| 44 | Cond’nal | 110 | 30 | 17 | 4 | 13 |
| 48 | Cond’nal | 150 | 30 | 17 | 5 | 12 |
| 49 | Cond’nal | 130 | 30 | 14 | 2 | 12 |
| 9 | PMR | 180 | 30 | 15 | 11 | 4 |
| 15 | PMR | 80 | 30 | 40 | *20* | *20* |
| 18 | PMR | 180 | 30 | 15 | 5 | 10 |
| 21 | PMR | 240 | 30 | 18 | 8 | 10 |
| 24 | PMR | 210 | 30 | 19 | 7 | 12 |
| 26 | PMR | 120 | 30 | 39 | *19* | *20* |
| 29 | PMR | 110 | 30 | 36 | *19* | 17 |
| 31 | PMR | 200 | 30 | 22 | 8 | 14 |
| 32 | PMR | 90 | 30 | 27 | *19* | *18* |
| 38 | PMR | 120 | 30 | 37 | *18* | *19* |
| 40 | PMR | 120 | 30 | 34 | 15 | *19* |
| 50 | PMR | 120 | 30 | 32 | 13 | *19* |

*Note*: Participant condition is indicated in the second column (*Conditional* is abbreviated to “*Cond’nal*”; PMR = Progressive Muscle Relaxation). Figures in Italics indicate correct responses on 90% (i.e., 18 out of 20) or more of trials in 1-Node and 2-Node in Phase 5 Test trials.

Figure 1.

Figure Caption

Figure 1: Mean total, mean 1-node and mean 2-node correct responses during derived relational responding test trials (Phase 5) for all three conditions.

**Appendix 1: PMR Instruction set script**.

Hello, make yourself comfortable. Sit back and close your eyes. I am going to read out some instructions I would like you to follow. Become aware of your breathing. Slowly, breathe in and out through your nose. On each exhale, say the word “one” to yourself. It is natural for thoughts to come into the mind. This does not mean that you are not following the procedure. When this happens, simply, just deal with the thought, do not dwell on it, but return your focus back to your breathing. Breathing in through your nose and exhaling on one. So now, deeply relax all your muscles, starting with your toes, feel them relaxing, all tension easing away, next your ankles. Completely relaxing, no tension at all. Relax the muscles in your calves. No strain. And your knees, feel them relaxing. And all the while, you are breathing in through your nose and exhaling on one. The muscles in your thighs are completely relaxed. The tension is easing away. And your lower back is totally at ease. Completely comfortable. Feel your stomach muscles relaxing. Everything is easing away. And your chest muscles, the tension is leaving them. You are totally at ease. Your hands are completely relaxed, just resting there. There is no tension in your arms. Completely relaxed. Your shoulders, there is no tension in them at all. Totally at ease. Your shoulder blades, feel them relaxing. Letting everything go. And all the while, you are breathing in and exhaling on one. All strains are leaving your neck. Completely relaxed. And your mouth is loosening up, all tension is easing away. Your cheeks are relaxing. Easing out. The lines of your forehead are disappearing. They are being rubbed away, and completely at ease. The top of your head is totally relaxing – no tension at all. Your whole body is completely relaxed. So now you are totally at ease, and continue to relax. Open your eyes whenever you feel ready. Someone will be with you in a few moments.