BRIEF REPORT

FAILURE TO SYSTEMATICALLY REPLICATE THE FACILITATIVE EFFECTS OF PROGRESSIVE MUSCLE RELAXATION ON DERIVED STIMULUS RELATIONS

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Behavior analysts, historically (e.g., Lattal & Harzem, 1984) and recently (e.g., Vyse, 2013), have discussed strategies and tactics to not only promote the survival of the experimental analysis of behavior as a field of inquiry but to strengthen it. One strategy is to continue to refine our understanding of the environmental control over derived, or emergent, stimulus relations (e.g., Critchfield, Barnes-Holmes, & Dougher, 2018). This improved understanding helps behavior analysts contribute to analyses of language, cognition, and other inter-disciplinary topics (e.g., Barnes-Holmes, Finn, McEnteggart, & Barnes-Holmes, 2018). Tyndall, Howe, and Roche (2016) adopted the tactic of examining derived relations in a manner appealing to other psychologists by investigating derived relations as a function of brief progressive muscle relaxation (PMR). From a behavioral perspective (Tyndall et al., 2016), PMR may exert its facilitative effects by sharpening stimulus control over emergent responding (i.e., by reducing the likelihood of extraneous forms of control such as when participants report "cognitive intrusions" during learning tasks).

Tyndall et al. (2016) exposed 35 adult participants to five phases. Across the initial three phases, participants learned arbitrary-matching-to-sample (AMTS) discriminations that could have developed into two 4-member stimulus-equivalence relations (A1/B1/C1/D1, A2/B2/C2/D2). In Phase 4, participants were assigned to one of three groups: PMR condition, Nonrelaxation Condition 1, and Nonrelaxation Condition 2. Participants in the PMR condition listened to an 11-min recording to induce deep relaxation. Participants in the two control groups completed either a simple- or conditional-discrimination task for a similar period of time. In the final phase, all participants received equivalence testing (C1/A1, C2/A2, D1/A1, D2/A2) in the absence of differential consequences. Approximately half of the participants in the PMR group responded successfully in equivalence testing, whereas only one participant did so across the control groups. These findings are important in demonstrating the facilitative effects of mindfulness-related techniques on human cognition (e.g., Cahn & Polich, 2006; Chambers, Chuen Yee Lo, & Allen, 2008), using even abbreviated (i.e., 10 to 12 min) techniques (e.g., Hudetz, Hudetz, & Klayman, 2000; Nava, Landau, Brody, Linder, & Schachinger, 2004). Given the novelty of these findings in the context of derived stimulus relations, it is critical to explore their generality.

One means of exploring the generality of Tyndall et al. (2016) is to examine the impact of brief PMR on derived relations using an assessment other than typical AMTS probe trials. Adduction is the emergence of a novel and complex composite skill after its simpler, component skills have been learned (e.g., Andronis, Layng, & Goldiamond, 1997; Chase, 2003; Epstein, 1987). Three studies have investigated the relation between derived relations and adduction (Arntzen, Petursson, Sadeghi, & Eilifsen, 2015; Bucklin, Dickinson, & Brethower, 2000; Rippy & Doughty, 2017). Bucklin et al. first taught participants AB and BC relations where the A, B, and C stimuli were, respectively, (previously learned) Hebrew symbols, nonsense syllables, and (already learned) Arabic numbers. In adduction testing, arithmetic questions were posed using the Hebrew symbols. For example, participants had to add A1 and A2 such that success-

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ful adduction required them to derive the untested, transitive AC relations and combine them with their extant math skills. Arntzen et al. extended these findings by demonstrating adduction involving relations other than transitive (i.e., symmetrical and equivalence); however, their participants already had derived these relations in probe-trial testing before adduction. Rippy and Doughty extended these two studies by measuring adduction involving untested equivalence relations. Group CA learned AB and BC relations (Arabic numbers [A], nonsense syllables [B], and nonrepresentational stimuli [C]), whereas Group EA learned AB, BC, CD, and DE relations (Arabic numbers [A], nonsense syllables [B, C, and D], and nonrepresentational stimuli [E]). This training could have established four, 3-member classes for Group CA and four, 5-member classes for Group EA, but neither group received derived-relations testing. The C and E stimuli for Groups CA and EA, respectively, were presented in adduction testing such that participants had to combine simple math skills with untested equivalence relations separated by one (Group CA) or three (Group EA) nodes. Successful adduction occurred for each CA participant but in only one EA participant. Whereas the positive CA results further confirmed the utility of adduction to measure derived relational learning, the negative EA results suggest a tactic to measure the impact of variables that potentially can facilitate difficult-to-derive relations.

The present research assessed the impact of brief PMR on derived relations by synthesizing the work of Tyndall et al. (2016) and the procedures applied to Group EA in Rippy and Doughty (2017). In Phases 1 and 3, participants were treated similarly to the Group-EA participants in Rippy and Doughty. They learned AB, BC, CD, and DE relations across Phase 1, and derived EA relations were measured in Phase 3 using arithmetic adduction testing. Critically, participants received 10 min of either the presence or absence of guided meditation to induce relaxation in Phase 2. Although Rippy and Doughty did not examine the effects of brief PMR, their results suggest that adduction involving three-node EA relations was possible but unlikely without additional intervention. Thus, at issue in the present research was whether the facilitative effects of brief PMR would be observed in adduction with untested, three-node equivalence relations. If demonstrated, the generality of brief PMR exposure would be revealed.

METHOD

Participants

Eight College of Charleston students (six female and two male) between the ages of 18 and 22 participated. The sample was collected by displaying flyers across campus and emailing first-year students with information about the study. Participants were told the research would involve one 3-hour laboratory visit, earning them approximately $30.00.

Apparatus

Phase 1 occurred in a smaller room with four workstations separated by dividers. Each workstation had a desk and chair. Each desk had an iMac or eMac, keyboard (which was not used by the participants), and mouse. The contingencies were programmed and responses were recorded using MTS version 11.6.7 (Dube, 1991). Phases 2 and 3 occurred in a nearby and larger conference room with one table and 12 chairs. In Phase 2, participants receiving PMR (see below) were provided with Parrot Zik 2.0 wireless headphones connected to an iPhone 7, and guided mediation was played using the iPhone application, Voice Memos. In Phase 3, participants completed, with a pen, 12 x 7 cm flashcards with arbitrary visual stimuli, numbers, and mathematical operations (see below).

Procedure

Table 1 outlines the three phases. There were five conditions in Phase 1, and all participants were treated identically. They first read these instructions:

> *Welcome to our study! In this part of the study, you will work alone on the computer for several sessions. In each session, the computer will present you with many trials. On each trial, you will be presented with one item, click on that item and additional items will appear. Click the mouse over any one of the surrounding items that you think "goes with" the one in the center,*

and one of two events will occur: (1) a star will appear on the screen or (2) the screen will darken. If a star appears, then you were correct and earned money. If the screen darkens, then you were incorrect and did not earn money. Your task is to earn as much money as possible. The computer will tell you when each session is over. When the session ends, you should find me next door. Good luck!

There were 96 trials in each session of Condition 1 wherein participants learned AB relations (see Table 2). The four AB (i.e., number to nonsense syllable) relations were presented such that each A sample stimulus occurred on 24 trials in each session. Across these 24 trials (e.g., A1), the correct comparison stimulus (e.g., B1) occurred in each screen corner six times. Every trial began with only a sample stimulus in the middle of the screen. After a click over it (observing response), the comparison stimuli immediately appeared with the sample. The stimuli were pseudorandomly organized such that each sample could not occur on more than three consecutive trials, and the correct comparison (S+) could not occur in the same location on more than three consecutive trials. Clicking the correct comparison immediately resulted in stars on the screen for 1 s. Clicking an incorrect comparison resulted in a 1.5-s dark screen. A resetting intertrial interval (ITI) of 1.5 s was used wherein the screen was blank. Condition 1 continued for at least two sessions and until there were no more than two errors per discrimination in the last session. The construction and execution of Conditions 2, 3, and 4 were identical to Condition 1 except that the participants learned the BC, CD, and DE relations in these conditions, respectively.

Each session in Condition 5 consisted of 192 trials. There were 48 trials each of the AB, BC, CD, and DE relations (12 trials with each sample). Across these 12 trials, the correct comparison occurred three times in each corner. Other procedural details (e.g., consequence delivery) remained unchanged from the initial conditions. The condition continued for at least one session and until there were no more than two errors per discrimination in a session.

Phase 2 commenced immediately after Condition 5. Participants were randomly assigned to the PMR or control group. Participants in the control group received these instructions:

Preparing your next session will take ten minutes. Please wait for your researcher to return to present you with the final session.

Participants in the PMR group received these instructions:

Your next session will require you to listen to a recording using headphones for ten minutes. It is recommended that you close your eyes while you listen. When the recording has finished, your researcher will return to collect you for your final session.

After participants read the instructions, the experimenter handed them the headphones, began the recording, dimmed the lights, and closed the door after leaving the room. A transcription of the recording is in the Appendix (the passage was identical to the one used by Tyndall et al. and was presented similarly).

Phase 3 occurred immediately after Phase 2, and the participants were treated identically. They first read these instructions:

Your next session will consist of me presenting you with 96 flashcards. Please calculate the answer and write it down. After you finish one card, I will hand you the next one. No feedback will be given during the session. However, after the session your answers will be assessed and money provided for each correct answer. Good luck!"

Table 3 shows examples of the flashcards (answers were not presented to participants such that each card was blank under the black line). The experimenter provided a pen and presented one flashcard at a time. The experimenter placed each completed flashcard to the side such that participants could not respond to previous flashcards. A limited hold for responding was set to 10 s such that the card was removed if 10 s elapsed without a response, which rarely occurred. The time between flashcards was only as long as it took for the experimenter

Table 1

Outline for training and testing for both groups.

		Discriminations	
Condition	Type	Trained	Tested
Phase 1			
1	Baseline training	AB	—
2	Baseline training	BC	—
3	Baseline training	CD	—
4	Baseline training	DE	—
5	Baseline training	AB, BC, CD, DE	—
Phase 2	PMR manipulation	—	—
Phase 3	Adduction Testing	—	EA

Note. Participants were treated differently only in Phase 2 receiving either the presence or absence of guided meditation for 10 min (see Appendix).

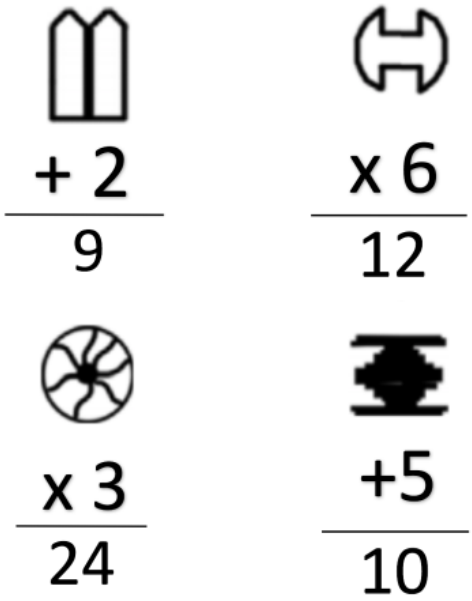
Table 2

Stimuli comprising the discriminations learned in Phase 1.

A1	B1	C1	D1	E1
2	yok	fic	het	
A2	B2	C2	D2	E2
5	mof	tep	sul	
A3	B3	C3	D3	E3
7	bal	loz	gix	
A4	B4	C4	D4	E4
8	kad	dut	roj	

Table 3

Examples of the flashcards from Phase 3 (the answers were not presented to the participants).



to place the previous flashcard to the side and present the next one. The experimenter did not provide any feedback following completion of each flashcard. As shown in Table 3, the flashcards presented participants with arithmetic questions involving the E stimuli from Phase 1. Each flashcard required participants to multiply (48 cards) or add (48 cards) an E stimulus with an Arabic number ranging from 1-12 (e.g., E1 + 9). Each E stimulus appeared on 24 flashcards (12 multiplication and 12 addition), and each Arabic number appeared on eight flashcards (four multiplication and four addition). The flashcards were organized pseudorandomly such that there were no more than three consecutive addition or multiplication problems, and no more than three consecutive flashcards with the same E stimulus.

RESULTS

Table 4 displays session-by-session accuracy scores for all participants. With only one exception, each participant in the control group completed the experiment in the minimum number of sessions. The exception was that Participant JR required a second session in Condition 5. There were three exceptions in the PMR group. Participants EL and OD required four sessions in Condition 1, and Participant EL required a second session in Condition 5.

Accuracy scores in the adduction assessment were similar across groups. Only one participant in each group achieved greater than 90% (Participants BB and BM in the PMR and control groups, respectively). Mean accuracies were 28.90% and 23.18% in the control and PMR groups, respectively. These accuracies were not significantly different: $t(6) = 0.1728$, $p = 0.8685$.

DISCUSSION

The present results do not extend the findings of Tyndall et al. (2016). Despite rapid and robust learning of the baseline relations, successful adduction occurred in only one of four participants in each group. These results confirm the challenge in adducing untested, three-node equivalence relations (Rippy & Doughty, 2017). Providing participants with brief PMR exposure did not overcome this challenge. As such, the present results limit the generality of brief PMR exposure at enhancing derived relational learning.

The discrepant results between the present research and Tyndall et al. (2016) might be attributed to three procedural differences. First, the number of possible equivalence classes was greater in the present research (i.e., four versus two). Second, the present research involved equivalence relations separated by three nodes, whereas Tyndall et al. examined one- and two-node equivalence relations. Third, Tyndall et al. assessed derived relations using AMTS probe trials, whereas adduction testing was utilized in the present work. Although numerous studies have established derived relations similar to four, 5-member equivalence classes (e.g., Arntzen, 2012; Fields & Moss, 2007; Hayes et al., 2001), it certainly is plausible that these two factors (class number and nodal distance) contributed to the findings. The results of Doughty and Soydan (2019) suggest that the third factor (testing method) may have contributed to the present findings. Two groups of college students received initial training identical to Phase 1 of

Table 4

Accuracy scores (i.e., percent correct) for each participant in each session.

	Participants			
Condition	BM	JR	MD	TH
Control Group				
AB	90	82	98	79
	98	100	98	100
BC	89	81	97	84
	100	100	100	100
CD	95	77	86	97
	99	100	100	100
DE	85	74	95	98
	100	98	100	100
AB – DE	98	96	98	99
		100		
Adduction	99	1	16	0
	BB	EL	GB	OD
PMR Group				
AB	82	40	98	25
	100	86	99	25
		97		92
		98		100
BC	96	86	95	90
	100	100	98	100
CD	95	96	95	91
	100	100	98	100
DE	97	92	94	94
	99	100	98	100
AB – DE	99	98	98	100
		99		
Adduction	93	0	0	0

the current experiment (i.e., AB, BC, CD, and DE relations were established). In Phase 2, derived EA relations were tested across groups using either probe-trial testing or a modified adduction assessment. The modified adduction assessment was identical to the adduction testing in the present experiment with one exception. Four response options (i.e., possible answers) were presented on each arithmetic flashcard surrounding the EA question. As such, both groups in Doughty and Soydan received an assessment in which sample and comparison stimuli were present. Despite this inclusion of comparison stimuli in the adduction assessment, no participant performed successfully in adduction testing, whereas each participant derived the EA relations in probe-trial testing. These findings attest to the relative difficulty inherent in deriving multi-nodal relations in an adduction assessment.

Future research examining the effects of PMR on derived relational responding should explore the aforementioned differences between the present research and Tyndall et al. (2016) as well as address the following limitations. Both Tyndall et al. and the present experiment omitted independent measures of relaxation during and after PMR exposure. The effects of prolonged PMR exposure were not assessed. It may be noteworthy to examine differential levels of PMR exposure across participants with and without a history of engaging in PMR to induce relaxation. An additional factor that may be useful to assess is the treatment of the control groups. Tyndall et al. utilized a simple learning task, whereas our participants were untreated. Finally, our small sample sizes should be noted. It is our hope that investigators continue to follow the lead of Tyndall et al., and others, and examine derived stimulus relations in the context of variables that garner attention in the broader scientific community.

REFERENCES

Andronis, P. T., Layng, T. J., & Goldiamond, I. (1997). Contingency adduction of "symbolic aggression" by pigeons. *The Analysis of Verbal Behavior, 14,* 5-17.

Arntzen, E. (2012). Training and testing parameters in formation of stimulus equivalence: Methodological issues. *European Journal of Behavior Analysis, 13,* 123-135.

Arntzen, E., Petursson, P. I., Sadeghi, P., & Eilifsen, C. (2015). Equivalence class formation in accuracy or speed conditions: Immediate emergence, adduction, and retention. *The Psychological Record, 65,* 141-159. doi: 10.1007/s40732-014-0097-9.

Barnes-Holmes, D., Finn, M., McEnteggart, C., & Barnes-Holmes, Y. (2018). Derived stimulus relations and their role in a behavior-analytic account of human language and cognition. *Perspectives on Behavior Science, 41,* 155-173. doi: 10.1007/s40614-017-0124-7.

Bucklin, B. R., Dickinson, A. M., & Brethower, D. M. (2000). A comparison of the effects of fluency training and accuracy training on application and retention. *Performance Improvement Quarterly, 13,* 140-163.

Cahn, B. R., & Polich, J. (2006). Meditation states and traits: EEG, ERP, and neuroimaging studies. *Psychological Bulletin, 132,* 180-211. doi:10.1037/0033-2909.132.2.180.

Chambers, R., Lo, B. Y., & Allen, N. B. (2008). The impact of intensive mindfulness training on attentional control, cognitive style, and affect. *Cognitive Therapy and Research, 32*, 303-322. doi: 10.1007/s10608-007-9119-0.

Chase, P. N. (2003). Behavioral education: Pragmatic answers to questions of novelty and efficiency. In K. A. Lattal & P. N. Chase (Eds.), *Behavior Theory and Philosophy* (pp. 347-367). New York, NY: Plenum/Kluwer.

Critchfield, T. S., Barnes-Holmes, B., & Dougher, M. J. (2018). What Sidman did: Historical and contemporary significance of research on derived stimulus relations. *Perspectives on Behavior Science, 41,* 9-32. doi: 10.1007/s40614-018-0154-9.

Critchfield, T. S., & Twyman, J. S. (2014). Prospective instructional design: Establishing conditions for emergent learning. *Journal of Cognitive Education and Psychology, 13,* 201-217. doi: 10.1897/1945-8959.13.2.201.

Doughty, A. H., & Soydan, J. A. (2019). Differential derived stimulus relations across probe-trial versus adduction testing are not a function of comparison-stimulus presentation. *Behavioural Processes, 103903.*

Dube W. V. (1991). Computer software for stimulus control research with Macintosh computers. *Experimental Analysis of Human Behavior, 9,* 28-30.

Epstein, R., 1987. The spontaneous interconnection of four repertoires of behavior in a pigeon (Columba livia). *Journal of Comparative Psychology, 101,* 197-201. doi:10.1037/0735-7036.101.2.197.

Fields, L., & Moss, P. (2007). Stimulus relatedness in equivalence classes: Interaction of nodality and contingency. *European Journal of Behavior Analysis, 8,* 141-159.

Hayes, S. C., Barnes-Holmes, D., & Roche, B. (2001). *Relational frame theory: A postSkinnerian account of human language and cognition.* New York: Kluwer Academic.

Hudetz, J. A., Hudetz, A. G., & Klayman, J. (2000). Relationship between relaxation by guided imagery and performance of working memory. *Psychological Reports, 86,* 15-20. doi:10.2466/PR0.86.1.15-20.

Lattal, K. A., & Harzem, P. (1984). Present trends and directions for the future (introduction to special issue). *Journal of the Experimental Analysis of Behavior, 42,* 349-351.

Nava, E., Landau, D., Brody, S., Linder, L., & Schächinger, H. (2004). Mental relaxation improves long-term incidental visual memory. *Neurobiology of Learning and Memory, 81,* 167-171. doi: 10.1016/j.nlm.2004.02.001.

Rippy, S. M., & Doughty, A. H. (2017). Adduction of untested derived stimulus relations depends on environmental complexity. *Behavioural Processes, 143*, 1-3. doi: 10.1016/j.beproc.2017.07.008.

Tyndall, I. T., Howe, B. E., & Roche, B. T. (2016). Exposure to progressive muscle relaxation leads to enhanced performance on derived relational responding tasks. *The Psychological Record, 66*, 213-222. doi: 10.1007/s40732-016-0163-6.

Vyse, S. (2013). Changing course. *The Behavior Analyst, 36,* 123-135. doi: 10.1007/s40614-014-0013-2.

APPENDIX

Below is a transcription of the guided-meditation recording presented to participants in the PMR group in Phase 2:

> Hello. Make yourself comfortable. Sit back and close your eyes. I am going to read out some instructions and I would like for you to follow. Become aware of your breathing. Slowly breathe in and out through your nose. Now, I would like for you to consciously begin inhaling for one, two, three, four. Now hold your breath for one, two, three, four, five, six, seven. And release for one, two, three, four, five, six, seven, eight. We are going to do this two more times. Begin to inhale for one, two, three, four. Now hold your breath for one, two, three, four, five, six, seven. And release for one, two, three, four, five, six, seven, eight. Inhale one, two, three, four. Hold. One, two, three, four, five, six, seven. Exhale. One, two, three, four, five, six, seven, eight. Now on each exhale, I would like for you to say the word "one," to yourself. It is natural for thoughts to come into mind. This does not mean that you are not following the procedure. When this happens, simply 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 of 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 of 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. Your lower back is totally and completely at ease. Completely comfortable. Feel your stomach muscles relaxing. Everything is easing away and your chest muscles. The tension is leaving them now. You are totally and completely at ease. You are totally and completely 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. Letting it all go. And all the while, you are breathing in and exhaling on "one." Now focus upon your neck. All strains are now leaving your neck. Completely relaxed. Now, notice your mouth. It is loosening up. Your tongue drops from the roof of your mouth. Your jaw relaxes softly. And your cheeks are relaxing. All easing out. And all of the while, you are breathing in and exhaling on "one." Completely and totally at peace. The lines of your forehead are now disappearing. The tension being held in the top of your head is now being rubbed away and you are feeling completely at ease. The top of your head is totally relaxing. No tension at all. Breathing in and exhaling on one. With each breath, imagining the tension releasing from your body. Exhaling any form of stress and tension that you may have built up during the day. Your whole body is now completely relaxed. You are now totally at ease and continue to relax. Open your eyes whenever you are ready. Someone will be with you in a few moments. Thank you.