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Reducing fear overgeneralization in children using a novel perceptual discrimination task

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ABSTRACT

Fear generalization, while adaptive, can be detrimental when occurring in excess. To this end a perceptual discrimination training task was created with a goal of decreasing fear overgeneralization. The current study tested the effectiveness of the training task among typically-developing children.

Participants (n = 73) were randomly assigned into a training, placebo or no task group. Following a differential fear-conditioning task, participants in the first two groups underwent the discrimination training or placebo task. An assessment task was then administered. Finally, all participants completed a fear generalization test, consisting of 11 morphs ranging in perceptual similarity from the threat cue to the safety cue. Physiological and self-report measures were collected.

Fear-conditioning was achieved in both physiological and self-report measures. Further, in the assessment task, the training group showed better perceptual discrimination than did the placebo group. Last, the training group exhibited less overgeneralization of affective stimuli as indicated by a physiological measure than did the two control conditions.

Findings suggest that the perceptual discrimination training task effectively moderated fear overgeneralization in children. This adds to previous evidence of the task's effectiveness among adults.

1. Introduction

Generalization is an adaptive mechanism whereby prior knowledge of a specific stimulus transfers onto a novel stimulus. However, excessive generalization may be maladaptive. Such is the case with fear overgeneralization, the process through which fearful characteristics are attributed to a novel, usually neutral, stimulus based on a previous association with a similar but dangerous stimulus. This often occurs when the two stimuli are perceived to share perceptual characteristics (see Goldstone, Medin, & Schyns, 1997). As fear overgeneralization of innocuous stimuli can lead to avoidance and subsequent functional impairment, recent attempts have been made to decrease fear overgeneralization in adults through perceptual discrimination training tasks (Ginat-Frolich, Klein, Katz, & Shechner, 2017; Lommen et al., 2017). However, no such attempts have been made with youth. Therefore, the aim of the current study is to examine the impact of a perceptual discrimination training task on fear generalization in a sample of typically-developing children.

The past decade has seen a surge in research exploring the mechanism of fear generalization in human adults. This is typically modeled by creating a continuum from a threat to a safety cue using either gradients of perceptual similarity (e.g., color, shape; for a review, see Dymond, Dunsmoor, Vervliet, Roche, & Hermans, 2015) or categorical belonging (e.g., mammals, vehicles; for a review, see Dunsmoor & Murphy, 2015). Participants' responses are measured either by self-report or physiological indices and plotted to form a curve representing the generalization gradient. Observed differences in the generalization gradient are then used to quantify fear overgeneralization, which is indexed by heightened levels of fear responding to stimuli on this continuum.

Fear overgeneralization can occur only after an initial fear has been established in connection with a specific stimulus. Differential fear conditioning tasks are often used to model this association in the laboratory. During fear acquisition, a neutral stimulus (conditional stimulus, CS) is repeatedly paired with an aversive stimulus (unconditional stimulus, US). Through this pairing, a new association is formed between the CS and US, resulting in the CS eliciting a fearful response in the absence of the US (threat cue; CS+). A second neutral stimulus is repeatedly presented alone, thereby signifying a lack of danger (safety cue; CS-). In contrast to studies with animal models where only

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physiological and behavioral responses are assessed, in human research, subjective ratings of fear are also collected. The use of multiple measures during both differential fear conditioning and generalization tasks is imperative, because physiological and self-reported indices assess different aspects of the fear response. Ultimately, the two indices, while different, are complementary.

Compared to the abundant differential fear conditioning studies conducted with adults or animals across development, research with human children is scarce, largely because of the complex methodological and ethical considerations related to fear learning research in developmental populations (see Shechner, Hong, Britton, Pine, & Fox, 2014). Further, the majority of developmental studies have focused on fear acquisition and fear extinction. Other fear-related mechanisms, such as fear generalization, have received less attention. Specifically, to the best of our knowledge, only two studies have examined fear generalization in typically-developing children (Glenn et al., 2012; Schiele et al., 2016), and one has done so with a clinical sample (El-Bar, Laufer, Yoran-Hegesh, & Paz, 2017). Additional studies have looked at generalization of extinction learning through threat/safety discrimination in both typically-developing children (Michalska, Shechner, Britton, Pine, & Fox, 2016) and clinical populations (Britton, 2013). Importantly, all of the above studies assessed perceptual fear generalization. Although it is difficult to directly compare across these studies, and further research is needed, it can be reasonably argued that fear overgeneralization occurs in children.

As the overgeneralization of fear is clearly maladaptive, recent attempts have been made to reduce it. To this end, a previous study with healthy adults assessed a novel perceptual discrimination training task aiming to increase basic perceptual discrimination and, as a result, improve affective learning (Ginat-Frolich et al., 2017). Following a differential conditioning task, participants were randomized to complete either the discrimination training or a placebo task. Thereafter, participants completed a discrimination assessment task, followed by a fear generalization test, consisting of 11 stimuli ranging in perceptual similarity from the CS + to the CS-. Results showed that the training group displayed better perceptual discrimination in the assessment task than did the placebo group. More importantly, this improvement transferred onto the affective stimuli in the fear generalization test, with participants in the training group showing less fear overgeneralization than did the placebo group.

Expecting similar effects in typically-developing children is reasonable for three reasons: first, the acquisition of fear through differential learning tasks has been found effective in studies with children (for review, see Shechner et al., 2014); second, children are able to distinguish between stimuli based on perceptual dimensions such as size and shape (see Goldstone, Medin, & Shyns, 1997); and third, children exhibit fear overgeneralization. The current study therefore sought to examine the effects of a perceptual discrimination training task on fear generalization, previously used with healthy adults, in a sample of healthy children. Given the limited number of studies assessing fear generalization in children, a third experimental condition was added. This “no task” group, who completed neither the perceptual discrimination training or placebo task nor the assessment task, served as an additional control by providing a picture of children's fear generalization patterns in the absence of an intervention.

The study has three primary hypotheses. First, children will achieve successful differential conditioning as measured by both self-reported fear and physiological indices. Second, following perceptual discrimination training, children will be better at discriminating between abstract shapes than will a placebo group. Third, improvement in perceptual discrimination will translate into enhanced discrimination of affective stimuli, ranging in perceptual similarity from a safety cue to a threat cue, resulting in decreased fear generalization in the training group.

2. Method

2.1. Participants

Seventy-six typically-developing children completed the entire procedure (age range: 9–14 years, $M = 12.09$ years, $SD = 1.77$; 52% female). An additional 8 participants asked to stop the experiment during the acquisition phase following the first-third US presentation (age range: 9.48–13.16 years, $M = 10.32$ years, $SD = 1.18$; 25% female). Participants were recruited through online advertisements and social media. An initial phone screening of potential participants was conducted with a legal guardian prior to participation; only children who met inclusion criteria were invited to participate. Exclusion criteria included: color blindness; any history or current psychiatric diagnoses or past or current use of psychiatric medication, with the exception of a diagnosis of attention deficit hyperactivity disorder (ADHD) and medication for ADHD; current psychological treatment; and any history of serious head injury. As we did not have a specific neural measure assessing brain function, children with ADHD were allowed to participate as long as their medication was active during the time of their participation. To ensure that this criterion was met, parents were both informed of this caveat during the initial phone screening and were also asked to confirm that their children's medication was active immediately before beginning the experiment. In total, seven participants with ADHD were included in the study, four of whom were in the placebo group, two of whom were in the training group and one of whom was in the no task group. The groups did not differ in ADHD ratio, X^2 (2, N = 73) = 2.107, $p = .349$. The study procedure was approved by the Institutional Review Board of the University and complied with the latest version of the declaration of Helsinki. The child's legal guardian signed a consent form, and children signed assent forms prior to their participation in the study. Participants were randomly assigned into one of three experimental conditions using Research Randomizer (Urbaniak & Plous, 2013). No group differences emerged in the demographic or clinical indices (all $ps > .119$) (see Table 1). All participants received modest compensation for their participation.

2.2. Instruments and measurements

Psychophysiological data were collected during fear conditioning and generalization tests with an 8 Slot Bionex system (MindWare Technologies Ltd., www.mindwaretech.com). Recordings were garnered using Mindware acquisition software (Version 3.0.13, MindWare Technologies Ltd.). Specifically, fear potentiated startle (FPS) was measured using electromyography (EMG) collected from two electrodes placed directly underneath the left eye of each participant, with an additional ground electrode placed on each participant's left forearm. An amplifier bandwidth of 30–500 Hz was used to filter the FPS-EMG signal, recorded at a sampling rate of 2000 Hz. During the experimental stages where FPS-EMG was measured (i.e., fear conditioning and

Table 1
Means and (Standard deviations) of demographic and clinical indices.

	Training	Placebo	No Task
Number of participants	$n = 27$	$n = 28$	$n = 28$
Age	11.98 (1.64) Range = 9.4–14.33	12.07 (1.9) Range = 9–14.65	11.69 (1.86) Range = 9–14.7
Gender	36% female	50% female	57% female
SCARED	23.35 (9.37)	24.2 (11.23)	20.31 (12.72)
CDI	9.7 (5.23)	8.92 (5.8)	7.54 (5.49)
Attrition	2	3	3

Note. Age in years. SCARED – Screen for Child Anxiety and Related Disorders, CDI – Child Depression Inventory.

generalization test), eye-blink response was elicited using a tactile startle probe in the form of a short burst of air (air puff) to participants' foreheads at second 5 or 6 of each stimulus presentation. During the fear conditioning stage alone, skin conductance response (SCR) was measured using two isotonic gel electrodes placed on the left palm (i.e., hypothenar and thenar muscles). SCR was recorded at a sampling rate of 25 Hz.

2.3. Self-reported measures

Before beginning the experiment, all participants completed Ishihara's test for color deficiency assessing possible color blindness (Clark, 1924). Before and after the fear conditioning stage of the experiment, self-report questionnaires were administered. Participants were asked to rate their level of fear in response to each CS using a Likert scale ranging from 1 (*not at all afraid*) to 10 (*extremely afraid*). In addition, CS-US contingency was examined following conditioning by asking participants to indicate the likelihood that each bell would ring, on a scale from 0% to 100%. Participants were also asked to rate the unpleasantness of the US on a scale from 1 (*not at all*) to 10 (*extremely*).

After the fear conditioning phase and before the fear generalization test, participants filled out two clinical questionnaires assessing anxiety and depression symptomatology: the Screen for Child Anxiety Related Disorders (SCARED, Birmaher et al., 1999) and the Children's Depression Inventory (CDI, Kovacs, 1984).

2.4. Procedure

Throughout the experiment, participants were seated in front of a 19″ monitor in a soundproofed room. All participants first underwent the pre-conditioning and conditioning stages of the bell differential fear conditioning task (Shechner et al., 2015). In this task, yellow and blue cartoon bells serve as the conditioned stimuli (CSs). Prior to beginning this stage of the experiment, over-ear headphones were placed on participants, who were then played a neutral 30 ms sound at 85 dB to ensure that the dB level was not deemed intolerable. Participants wore these headphones for the duration of the fear conditioning task. If a child found the volume too aversive, it was decreased by five dB. Participants were then informed that they might hear unpleasant sounds and feel an air puff on their forehead. They were also told that if they paid attention, they might learn to predict when the sound would occur, but they were not informed of the CS+/US pairing. Each bell appeared in the center of the screen for 8 s per presentation. In the pre-conditioning stage, each bell was presented four times. Thereafter, in the conditioning stage, each bell was presented ten times. One of the bells was paired with a straight-toned aversive sound (US) at an 80% reinforcement rate (CS+; threat cue). The second bell was never paired with the US (CS-; safety cue). The order of the CSs in both fear conditioning stages was pseudo-randomized into two versions, and the order and color of the CSs were counterbalanced between participants (see Fig. 1).

Following fear conditioning, the headphones were removed. Participants 1) completed the perceptual discrimination task, 2) completed a placebo task, or 3) did not complete any task and proceeded to fill out questionnaires and complete the fear generalization test. Participants were randomly assigned to the experimental groups immediately after signing the consent forms and before starting the experiment.

2.4.1. Perceptual discrimination training

The perceptual discrimination training task was an adapted version of the training task described in a previous study (see Ginat-Frolich et al., 2017). In this training task, white outlined geometric shapes were presented on a black background in predesignated shape pairs. Each trial consisted of a presentation of a target image from the predesignated pair in the center of the screen (4s), followed by a fixation cross (2s). Thereafter two shapes appeared on the screen, one identical to the target and one different from it. Participants were asked to identify the shape they had not seen previously by selecting either the S (left) or L (right) key on a standard keyboard (see Fig. 2). The target shape was randomized between participants. Shape pairs differed in contour or size and appeared sequentially at an increasing level of difficulty (for a detailed description, see Ginat-Frolich et al., 2017).

To better address individual differences and to increase the task's effectiveness, several changes were made to the original training task used in the adult study. First, to increase difficulty, differences between shape pairs were restricted to a single domain (i.e., shape or size). In addition, the first 3 difficulty levels in the previous study were deemed unnecessary, as the majority of participants (> 90%) achieved 100% accuracy. Therefore, these levels were removed, leaving a gradient of increasing difficulty from 1 (*somewhat different*) to 6 (*very similar*). Gradient levels 1–5 each had three shape pairs, and gradient level 6 had 12 shape pairs. This resulted in a total of 27 shape pairs in the

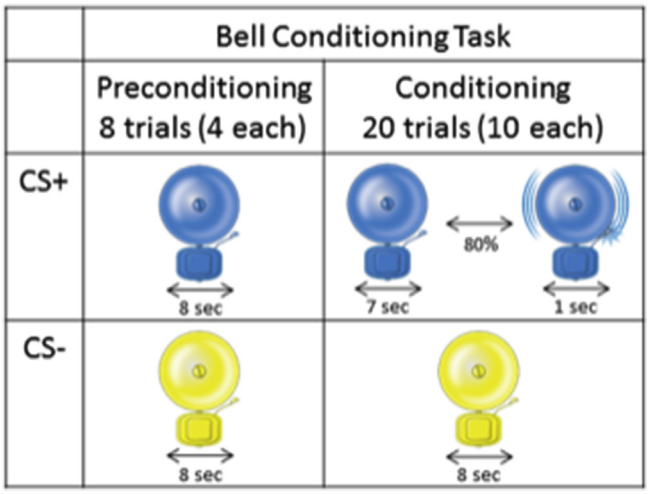

Fig. 1. Title: Bell conditioning task. Legend: This figure presents the stages of the bell conditioning task. During the pre-conditioning phase, each bell appears four times (for a total of eight trials). During the conditioning phase, each bell appears ten times (for a total of 20 trials). The CS+ is paired with the US for eight out of the 10 presentations during this phase (partial reinforcement rate of 80%).

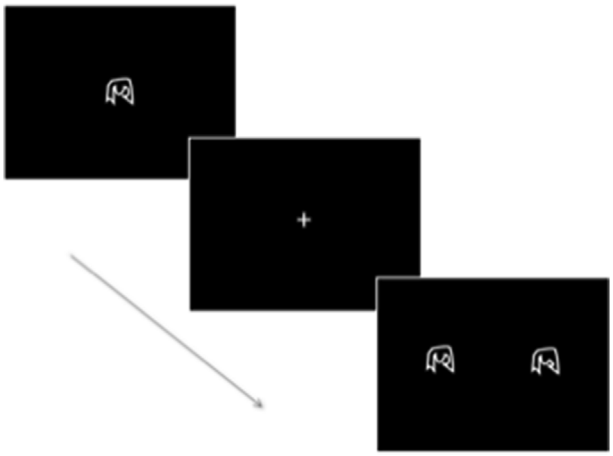

Fig. 2. Title: Perceptual discrimination training task. Legend: This figure provides an example of one trial from the perceptual discrimination training task. During the training, a target shape is presented in the center of the screen (4s), followed by a fixation cross (2s). Thereafter two shapes appear on the screen, one identical to the target and one different from it. Participants are asked to identify the shape they have not seen previously.

experimental block of the training task, with a sequential presentation of each difficulty class. The pairs in each gradient level appeared twice, with the shape that differed from the target image randomized on the right or left side of the screen (for a total of 54 trials). An additional three shape pairs were used in a practice block, administered prior to the experimental block.

Participants received feedback on correct and incorrect responses. Following a correct answer, the screen turned magenta, and a sentence reading "Good job!" appeared. Following an incorrect answer, the screen turned red, and a sentence appeared saying "Try again." In the practice block, if participants gave an incorrect answer, they could immediately repeat the trial and could keep repeating it until they got the correct response. In contrast, if participants answered incorrectly during the experimental block, they proceeded to the next trial. In order to proceed to the next difficulty level, participants had to achieve above 60% accuracy. If their accuracy was under 60%, in levels 1–5, the complete level was repeated (i.e., the participant was shown the set of 6 shape pairs for a second time). The accuracy of all presentations within the level was then recalculated (i.e., in this case, the accuracy achieved across the 12 shape pair presentations). If above 60% accuracy was achieved, the participants continued to the next level; if it was under 60%, they were shown the set of shape pairs in the current level once again. At the end of each set of presentations, accuracy was recalculated for the total number of trials. The same algorithm was used for level 6, but in this case, if participants failed to achieve 60% accuracy following the initial 24 shape pair presentations, the set-size for level repetition was set to 12, and accuracy was recalculated.

Total training time was capped at 20 min. Participants who reached the 20-min mark while in the middle of a gradient level, completed the current set of repetitions and the training ended irrespective of achieved accuracy.

2.4.2. Placebo task

The placebo task used the same geometric shapes as the training task. Following a fixation point, each shape appeared randomly on either the right or left side of the screen. Participants were asked to assess where the shape had appeared by pressing the S (left) or L (right) key. Participants received no feedback on their responses. To ensure that the duration of the placebo task be comparable to that of the training task, some shapes appeared twice pseudo-randomly, for a total of 216 shape presentations.

2.4.3. Discrimination assessment task

After completing the training or placebo tasks, participants underwent an assessment task to measure their ability to perceptually discriminate between geometric figures. A set of 60 novel geometric predesignated shape pairs was created for the assessment task. Of the pairs, 30 were identical, 15 differed in contour, and 15 differed in shape. All shape pairs that differed were in line with the highest difficulty gradient level (i.e., 6) in the training task. During this task, the shapes in each predesignated pair appeared on the right or left side of the screen (2s). Participants were asked to indicate whether the images they had seen were identical or different as quickly and accurately as possible, using the D and K keys on a standard keyboard; these were labeled with blue and red stickers.

2.4.4. Fear generalization test

The last stage of the experiment was a fear generalization test. During this stage, the over-ear headphones were replaced and participants viewed 11 bell morphs (GSs) ranging in color from the CS- to the CS+ (see Fig. 3). The task was comprised of a behavioral assessment phase, where self-reported risk ratings were collected, and a passive viewing phase, where only FPS was measured. In both phases, each morph appeared on the screen for 8 s. During the behavioral phase, each set of bells appeared four times for a total of 44 presentations. The morphs were presented randomly within each set. During each bell presentation, participants were asked to assess the bell's level of risk ("*What is the likelihood that this bell will ring*?") on a 7-point Likert scale from 0 (*not at all likely*) to 6 (*extremely likely*). The risk rating could be provided from the onset of the bell presentation, but once selected, participants were asked to lock in their answer (by right clicking their mouse). Once locked in, their answer could not be altered. In the subsequent physiological block, each set of bells appeared 8 times for a total of 88 presentations, with the bells randomized within each set. An air puff was administered pseudo-randomly at second five or six during each trial, and FPS was assessed using FPS-EMG. In addition, in line with similar studies, reminder blocks consisting of a CS-US pairing and an additional presentation of the CS- were included (for example, see S. Lissek et al., 2008). There were three reminder blocks: one before and after the behavioral block and a third after the first four set presentations during the passive viewing phase.

All tasks were programmed using E-Prime 2.0 Pro.

2.5. Data analysis

2.5.1. Fear conditioning

The pre-conditioning and conditioning stages consisted of three dependent variables: self-reports, FPS-EMG, and SCR. Further, group was included in all analyses as an independent variable. Mindware data analysis software (Version 3.0.25) was used to analyze FPS-EMG and SCR responses. FPS-EMG responses for each trial were measured in a 200 ms window following the administration of an air puff. Each score was then standardized using within-subject T-score transformations. SCR was measured for each CS as a trough-to-peak amplitude in a 4.5 s window, from 500 ms to 5 s following stimulus onset, and a square root transformation was used to normalize scores for each participant. For both FPS-EMG and SCR, an average response to each CS in each phase was created per participant. Differences between phase (pre-conditioning and conditioning) and stimulus (CS+ and CS-) were assessed via repeated measures ANOVAs using SPSS (version 20). This allowed for a within-subject assessment of the main effects.

2.5.2. Perceptual discrimination assessment task

An average correct response score on the discrimination assessment task was created for each participant and between-group differences were examined using an independent-samples *t*-test. In addition, a secondary analysis using a linear regression was conducted to assess the association between total correct responses and participants' age (ageXgroup interaction). Of note, only the training and the placebo groups were tested using the discrimination assessment task.

2.5.3. Fear generalization test

A mean score in response to each GS was calculated separately for both the self-report and passive viewing stages (FPS-EMG). Longitudinal designs of growth are often applied in studies focusing on associated changes following an intervention, as these models may provide clues to an intervention's effectiveness (Duncan & Duncan, 2004; Rogosa, Brandt, & Zimowski, 1982). In addition, multilevel modeling techniques are commonly used to assess fear generalization gradients (Britton, 2013; Ginat-Frolich et al., 2017; Michalska et al., 2016; Shechner et al., 2018; Vanbrabant et al., 2015). Classical linear longitudinal models typically involve a single growth profile to represent linear changes in an outcome variable across time, but this does not always fit the empirical data. Importantly, piecewise linear mixed-effects models allow the investigation of different linear functions of time corresponding to the pre- and post-critical time point trends (McGee & Carleton, 1970). For this reason, piecewise linear mixed effects models using the PROC MIXED (SAS 9.4) were selected to assess data from this experimental stage. Participant group was defined as a between-factor independent variable and fear generalization of the GSs as a within-subject predictor. A model was then defined with two GS-related slopes: 1) linearity before the 50% morph (including 50)

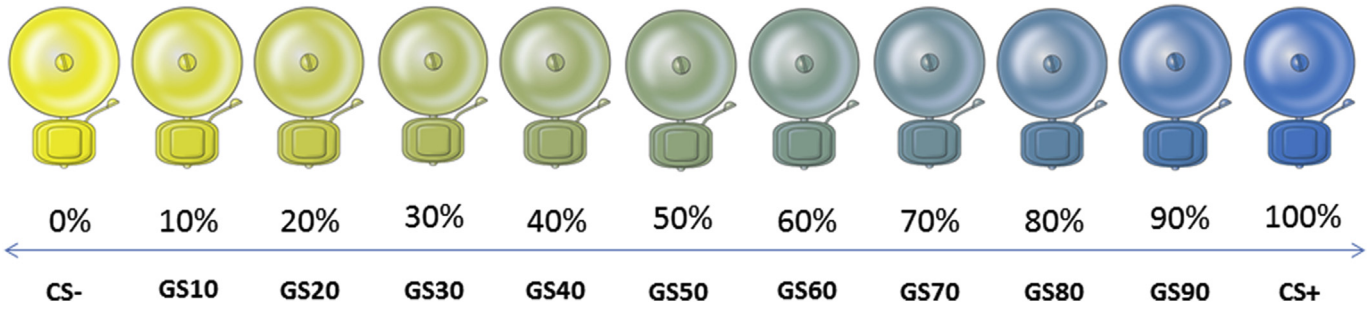

Fig. 3. Title: Fear generalization test. Legend: This figure presents the 11 bells used in the fear generalization test, ranging in perceptual similarity from the CS- (0%) to the CS+ (100%).

examining the CS- and GSs perceptually similar to the CS- (generalization around the safety cue), and 2) linearity after the 50% morph examining the CS+ and GSs perceptually similar to the CS+ (generalization around the threat cue). This was defined for both FPS-EMG and self-report outcomes. Notably, the model assumes both slopes can be moderated by group. Significant interactions between GS morph slopes and group were further decomposed by examining a series of predefined contrasts to assess the pattern of the interaction. These included the difference between the threat (CS+) and safety (CS-) cues in each group, as well as between-group differences in the safety cue (CS-). A simulation-based multiple-tests correction was used to adjust for type-one error inflation (Edwards & Berry, 1987). Between and within-group differences in response trends were assessed, with a Gaussian distribution of residuals assumed for both self-reported and FPS-EMG data. So as to provide a preliminary understanding of the role of perceptual acuity during this phase, an exploratory secondary analysis was conducted. To this end, perceptual acuity, as measured by participants' score on the discrimination assessment task (training and placebo groups only), was used as a covariate in the above analysis.

Alpha = 0.05 was set as statistical significance for all analyses.

3. Results

Two participants were excluded from the final analysis: one for excessive movement and the other for high clinical indices. The final sample included 73 participants (aged: 9–14.72 years, $M = 12.09$, $SD = 1.77$; 50.7% female), with 23 participants in the training group, 25 in the placebo and 25 in the no task groups. No group differences emerged in age, gender, or the administered clinical questionnaires (all $ps > 0.258$).

3.1. Fear conditioning

For self-reported fear, a significant phase-by-stimulus interaction emerged, $F(1,70) = 61.99$, $p < .001$. Post-hoc analyses revealed that participants reported significantly higher fear towards the CS+ ($M = 3.78$, $SD = 3.13$) than the CS- ($M = 1.66$, $SD = 2.02$) in the conditioning phase, $t(73) = 7.21$, $p < .001$. However, no difference was observed between the CS+ ($M = .81$, $SD = 1.55$) and the CS- ($M = .84$, $SD = 1.53$) during the pre-conditioning phase, $t(73) = -.189$, $p = .85$. The three-way interaction of phase-by-stimulus-by-group was non-significant, $F(2, 70) = 2.953$, $p = .059$. Further, a moderate overall level of aversiveness was reported in response to the US ($M = 6.32$, $SD = 2.87$), and no between-group differences emerged, $F(2,70) = .834$, $p = .439$.

For the measure of FPS-EMG, a significant phase-by-stimulus interaction emerged, $F(1,64) = 4.31$, $p = .042$. Once again, post-hoc analyses revealed a significant difference between the CSs during the conditioning phase, with the CS+ ($M = 48.31$, $SD = 4.95$) higher than the CS- ($M = 46.93$, $SD = 4.88$), $t(66) = 2.49$, $p = .015$. During the pre-conditioning phase, however, no such difference emerged between the CS+ ($M = 54.39$, $SD = 6.5$) and the CS- ($M = 55.24$, $SD = 6.63$), $t(66) = -.987$, $p = .327$. The three-way interaction of phase-by-stimulus-by-group was non-significant, $F(2, 64) = 19.168$, $p = .367$.

Finally, for the measure of SCR, a significant phase-by-stimulus interaction emerged, $F(1,63) = 18.99$, $p < .001$. As before, post-hoc analyses revealed a significant difference between the CS+ ($M = .188$, $SD = .117$) and the CS- ($M = .133$, $SD = .089$) in the conditioning phase, $t(65) = 5.191$, $p < .001$. No such difference emerged between the CS+ ($M = .132$, $SD = .098$) and the CS- ($M = .147$, $SD = .112$) in the pre-conditioning phase, $t(65) = -1.065$, $p = .291$. The three-way interaction of phase-by-stimulus-by-group was non-significant, $F(2, 63) = 0.022$, $p = .979$ (see Fig. 4).

3.2. Perceptual discrimination assessment task results

To assess the impact of the discrimination training, an assessment task was administered to the training and placebo groups. A significant difference emerged in the average correct responses of the training group (58.33%) and the placebo group (54.07%), $t(46) = 2.165$, $p = .036$. The training group was better able to discriminate between novel geometric shape pairs than the placebo group. In addition, there was a significant interaction between age and group (ageXgroup), $F(1, 44) = 5.897$, $p < .002$. Older participants achieved higher accuracy in the training group; however, age did not affect performance in the placebo group.

3.3. Fear generalization test

3.3.1. Self-reported risk assessment

No significant group-by-stimulus interaction was found for self-reported risk. Of note, however, a significant main effect of stimulus did emerge, $F(1,3114) = 3.6$, $p < .001$, presenting a similar generalization pattern to that seen in SR risk patterns in studies with healthy participants (see Fig. 5).

3.3.2. FPS-EMG results

In the slopes of the CS- to the 50% morph, the fixed effects in the piecewise linear mixed effects model procedure displayed a significant group-by-stimulus interaction, $F(2,684) = 15.84$, $p < .001$. This indicates that as GSs became increasingly similar to the CS-, there was a significant difference between the three groups in physiological responses. Specifically, the training group exhibited a linear slope [estimate = 3.9464, SE = 0.5098, $t(684) = 7.74$, $p < .0001$], while linearity in the placebo [estimate = 0.000341, SE = 0.005330, $t(684) = 0.06$, $p = 1.000$] and no task [estimate = 0.009071, SE = 0.005103, $t(684) = 1.78$, $p = 0.3264$] groups proved non-significant. Indeed, FPS-EMG responses in the two control groups increased as they became similar to the CS-, but in the training group, they decreased. Of note, no significant interaction was observed in the slopes above the 50% morph through to the CS+, $F(1,684) = 1.64$, $p = 0.1952$. In all three groups, responses to GSs increased as morphs

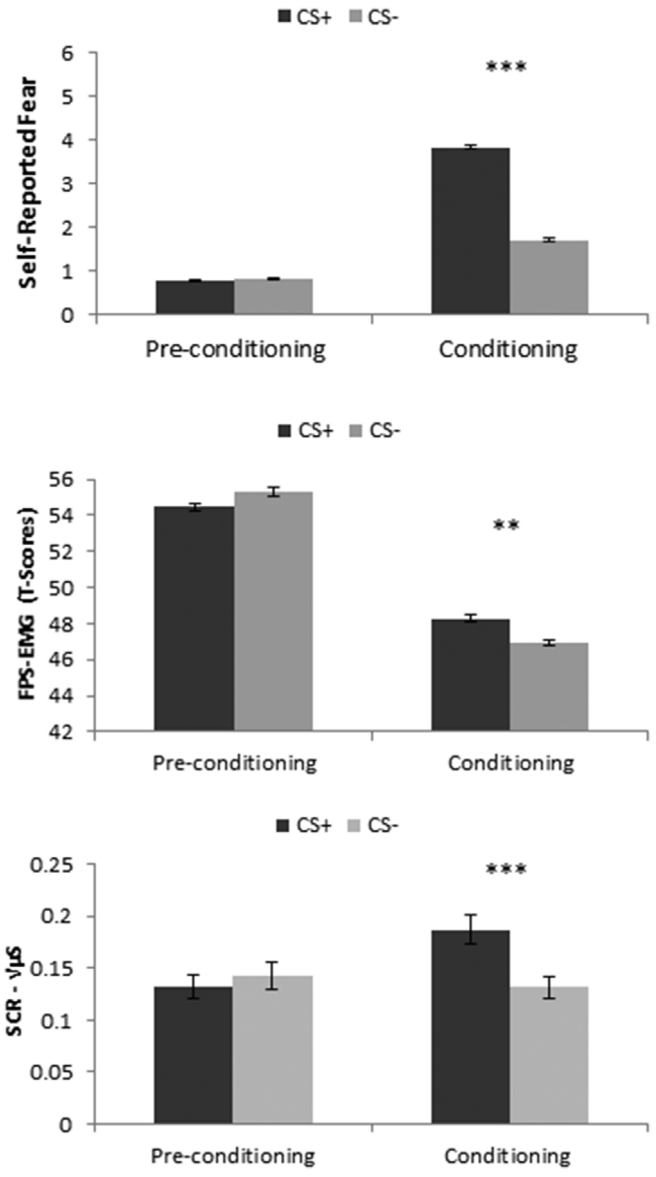

Fig. 4. Title: Fear conditioning results. Legend: The results from the pre-conditioning and fear conditioning phases of the experiment for each of the three experimental measures (i.e., self-report, FPS-EMG, and SCR) are presented.

became more perceptually similar to the CS+.

In additional pre-defined contrasts, between-group differences also emerged. A significant difference was found between the CS+ and CS- in the training group [estimate = 3.9464, SE = 0.5098, $t(684) = 7.74$, $p < .0001$], with participants exhibiting more arousal when shown the CS+. This difference was not observed in the placebo [estimate = 0.1337, SE = 0.5212, $t(684) = 0.26$, $p = .9997$] or no task [estimate = 0.9763, SE = 0.4990, $t(684) = 1.96$, $p = .2374$] groups. Together, these findings indicate that the training group exhibited less overgeneralization of fear than did the other two groups. FPS-EMG results of all three groups are presented in Fig. 6.

Two separate secondary analyses were conducted using two potential covariates: participants' FPS-EMG response to the CS- during fear conditioning and perceptual acuity, as measured by overall scores in the discrimination assessment task. Both were found to be non-significant. Indeed, in both cases, adding these covariates did not affect the group-by-stimulus interaction or the above predefined contrasts. When adding participants' FPS-EMG response to the CS- during fear conditioning, the difference between the CS+ and CS- previously observed during the fear generalization test remained significant in the training group ($p < .0001$). No such difference was observed in the placebo ($p = .6278$) or no task ($p = .2273$) groups. Similarly, when adding perceptual acuity, the difference between the CS+ and CS- previously observed during the fear generalization test in the training group remained significant ($p < .0001$), and no such difference was observed in the placebo group ($p = .8263$). Of note, for the measure of perceptual acuity, only the training and placebo groups were included as the no task group did not complete the discrimination assessment task.

Finally, no significant results emerged for any of the clinical questionnaires.

4. Discussion

The aim of the current study was to assess the effect of a perceptual discrimination training task on improving basic perceptual discrimination and its possible impact on affective learning in typically-developing children. This was tested in the context of differential fear learning, with participants randomized into one of three groups: a perceptual discrimination training group, a placebo group, and a group that completed neither task. Three major findings emerged. First, fear conditioning was observed in both self-reported and physiological measures. Second, participants in the training group achieved more correct responses than participants in the placebo group during the discrimination assessment task. Third, during the fear generalization test, participants' self-reported risk assessment showed a gradual

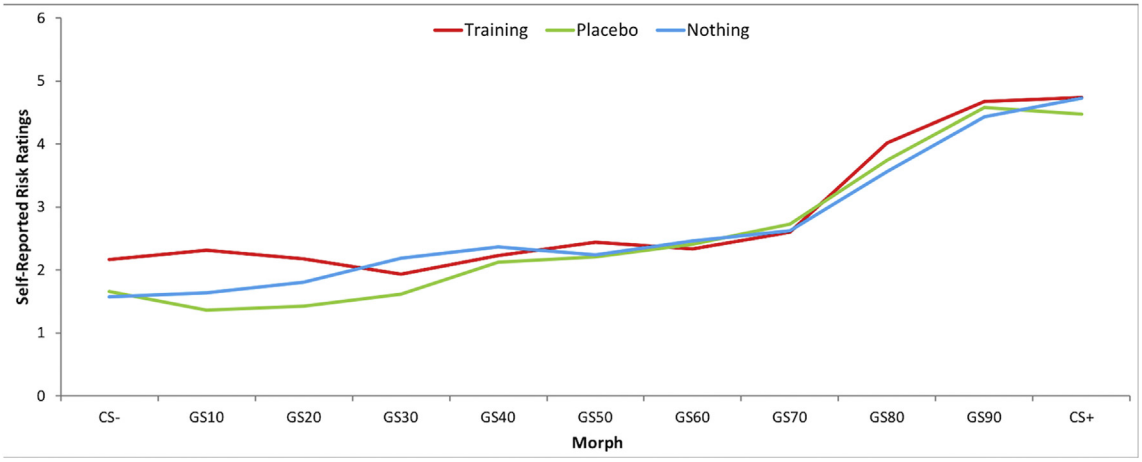

Fig. 5. Title: Self-reported risk ratings during the fear generalization test by group. Legend: Participants' self-reported risk ratings (y-axis) in response to each morph in the fear generalization test (x-axis) are presented in this figure by group.

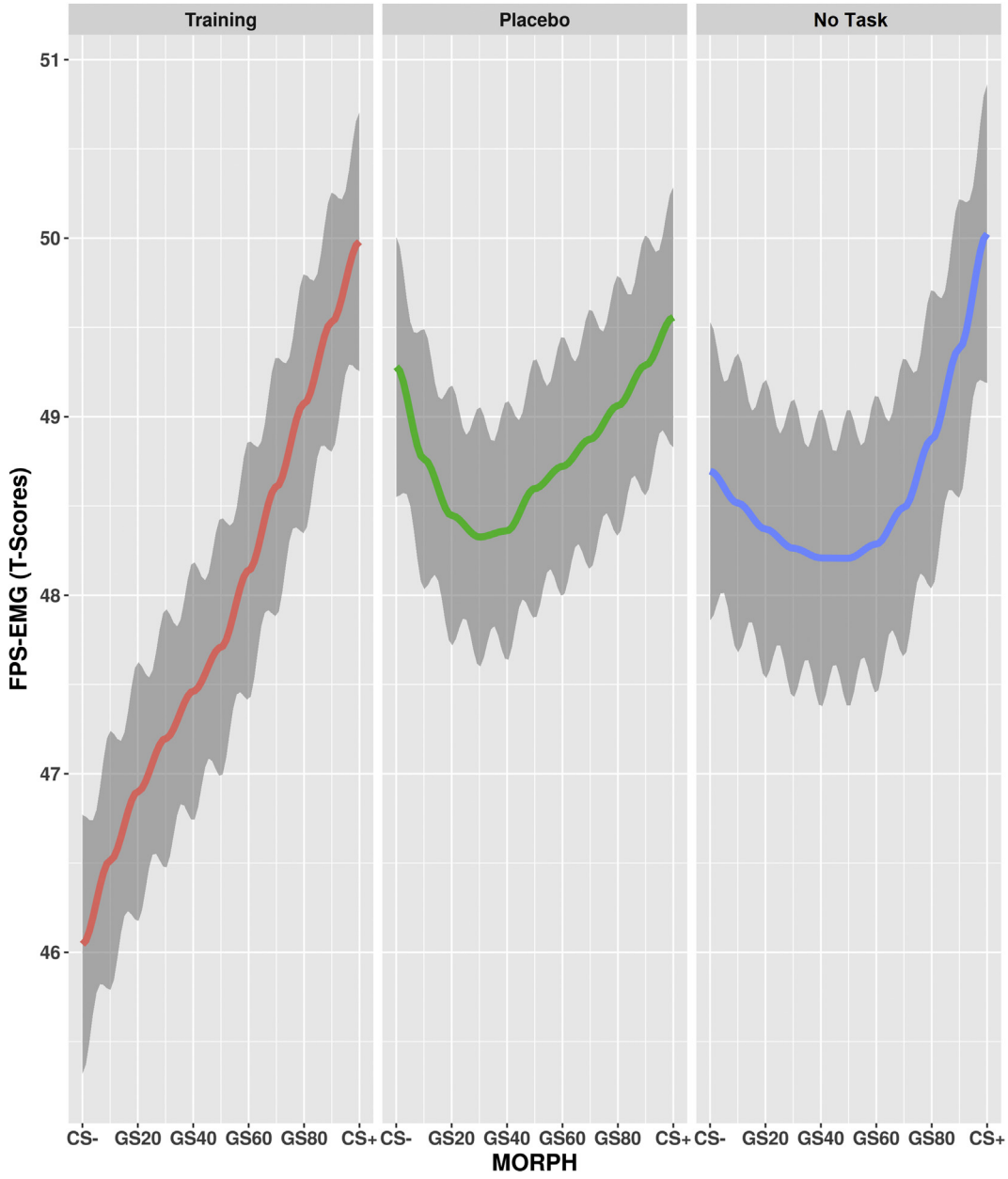

Fig. 6. Title: FPS-EMG during the fear generalization test by group. Legend: The measure of FPS-EMG (y-axis) in response to each morph in the fear generalization test (x-axis) are presented in this figure by group.

increase from the CS- to the CS+, but no between-group differences emerged. However, group differences were found in the measure of FPS-EMG, where the perceptual discrimination training group exhibited less fear overgeneralization than the other two groups.

In line with our first hypothesis, fear conditioning was evident in multiple measures. This finding adds to the growing body of research that has successfully used fear conditioning tasks with children (for review, see Shechner et al., 2014). Moreover, as in previous studies using the bell conditioning paradigm, over 90% of our participants were able to complete the fear acquisition stage of the experiment. This suggests that the bell conditioning paradigm is developmentally appropriate for children (Michalska et al., 2016; Shechner et al., 2015).

In line with our second hypothesis, performance on the discrimination assessment task, which assessed improvements in perceptual discrimination following the training and placebo tasks, was better in the training group than in the placebo group. This adds to findings from a previous study using the same perceptual discrimination training task with healthy adults, which similarly found that the training task increased basic perceptual discrimination (Ginat-Frolich et al., 2017). Nonetheless, between-group differences in the total correct responses on the assessment task in the current sample were modest. A recent review of perceptual learning suggests that mere exposure to similar stimuli, be they simple or complex, can improve perceptual discrimination (Mitchell & Hall, 2014). Therefore, it is possible that simply viewing the geometric shapes in the placebo task resulted in moderately improved perceptual discrimination abilities among our participants, thereby mitigating the group differences in the assessment task.

Further, the training group's overall correct responses in the assessment task indicate that a relatively short training session can improve basic perceptual discrimination, as has been seen in similar single session training procedures (for example, see Goldstone, 1995). However, the improvement following the training, as measured by the assessment task, was more modest in the current sample than the improvement observed in a previous study using the same training task

with adults (Ginat-Frolich et al., 2017). In a secondary analysis, overall accuracy in the training group was moderated by age, with older children receiving more overall correct responses. This effect was not seen in the placebo group. Taken together, these findings imply that the training task becomes more effective with age. This increased effectiveness likely stems from the procedure of the task itself. Though all children in the training group completed the training task, it is possible that younger children found its length taxing and the stimuli used to be dull. Therefore, adapting the training task specifically for child populations by selecting more age-appropriate stimuli and adapting the task's length could increase its effectiveness with younger children.

The study's third hypothesis was partially confirmed, with group differences emerging in the measure of FPS-EMG but not in self-reported risk ratings. Specifically, all three groups showed comparable risk assessment to discrete morphs during the fear generalization test. A main effect of stimulus was observed, with all groups providing low self-reported risk ratings to morphs perceptually similar to the CS- and high risk ratings to morphs close to the CS+. These results are similar to self-report generalization gradients of risk assessment in studies with both healthy adults (e.g., S. Lissek et al., 2008) and children (e.g., Schiele et al., 2016), suggesting that healthy children are able to adaptively judge risk based on perceptual characteristics.

Though the discrimination assessment task showed that participants in the training group had improved perceptual discrimination abilities, this did not translate into more adaptive risk assessment of affective stimuli. Notably, while risk assessment involves perceptual elements, it engages additional cognitive processes. Indeed, threat appraisal is context dependent and is influenced by additional factors, such as stimulus category. Current attempts to distinguish these factors as they relate to fear generalization are promising, offering insight into the multiple dimensions involved in categorizing GSs as dangerous or safe (for review, see Struyf, Zaman, Vervliet, & Van Diest, 2015; Struyf, Zaman, Hermans, & Vervliet, 2017).

In contrast to participants' self-reported risk ratings, group differences emerged in the fear generalization test for the measure of FPS-EMG. Specifically, the training group exhibited decreased fear overgeneralization compared to the placebo and no task groups. This was evident in two ways. First, when looking at the slopes of the GSs before and after the 50% morph, the GSs after the 50% morph all showed a similar pattern. All groups began with a strong response to the CS+, but this decreased as the morphs contained less perceptual components of the threat cue. This decrease continued from the 50% GS to the CS- in the training group, but in the placebo and no task groups, responses once again increased as morphs became more similar to the CS-. This resulted in a difference between the CS+ and CS- (i.e., decreased fear generalization) in the training group only. In contrast, the lack of difference between the CS+ and CS- in the two control groups is indicative of fear overgeneralization.

Taken together, the results in the measure of FPS-EMG suggest that the improvements in basic perceptual discrimination gained from the training task transferred onto affective stimuli, though no group differences emerged for the measure of self-reported risk assessment. These results highlight the different dimensions of fear responding measured by physiological and verbal indices, further emphasizing the importance of using multiple assessment measures when studying fear learning (Fanselow & Pennington, 2017).

Though the current study's results are promising, it has several limitations. First, it was conducted with typically-developing children who, though perhaps not to the same extent as adults, were hypothesized to show adaptive perceptual discrimination. The impact of the training task was therefore hypothesized to be modest before the study began. Further research should assess the training task with children suffering from anxiety related psychopathology, as it is in this population that deficits in perceptual discrimination are assumed to occur. Second, the single session of perceptual discrimination training, as well as the within-study design, make it impossible to conclude the long-term effects of the training task. The task is currently being put on an online platform, and future research will include multiple sessions of the training task, as well as a follow-up assessment. Third, disentangling where perception ends and cognitive strategies begin is difficult. Though the SR risk-assessment question in the fear generalization test addressed a level of perceptual discrimination acuity, a question addressing basic perceptual discrimination ability during this phase was not included. Such a question – for example, in the current paradigm, "is this the bell that rang?" – would facilitate an assessment of basic perceptual discrimination in affective learning and should be included in future studies. This is of particular importance, in light of perceptual acuity, as measured by participants' scores on the generalization assessment task, not affecting the results of the fear generalization test. Further, given that the differences observed during this phase emerged primarily in morphs closely related to the CS-, it is difficult to isolate whether these differences are derived from perceptual discrimination or processes more related to safety learning.

In conclusion, perceptual discrimination training could be an important avenue through which to decrease fear overgeneralization in children. As it is a key characteristic of anxiety-related disorders, and with anxiety disorders being the most prevalent psychopathology among children (Beesdo, Knappe, & Pine, 2009), such a reduction could have significant clinical implications. Further, to maximize efficacy, an effort should be made to ensure that training tasks are tailored for use with developmental populations. Future research should be conducted using an adapted perceptual discrimination training task specifically created for use with child populations.

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