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Acquired equivalence in veterans with symptoms of posttraumatic stress: reexperiencing symptoms are associated with greater generalization

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Abstract

The severity and number of reexperiencing symptoms (e.g. flashbacks) show considerable variability across individuals with post-traumatic stress disorder. One interpretation of reexperiencing symptoms invokes generalization: specifically, the traumatic memory may be stored in such a way that neutral stimuli that only vaguely resemble some feature of the traumatic event are sufficient to trigger the memory. If this is the case, then individuals with higher levels of reexperiencing symptoms might show greater generalization, even in contexts unrelated to trauma. In the current study, an acquired equivalence (AE) test was used to assess associative learning and generalization in 114 veterans, who were self-assessed for posttraumatic stress disorder (PTSD) symptoms and given a test of declarative memory. After controlling for demographic variables, psychoactive medication use, and initial learning, regression analyses indicated that the number of PTSD reexperiencing symptoms significantly improved the model for generalization ($\beta = -.23$) but not associative learning or declarative memory. The results support the idea that generalization is linked to reexperiencing symptoms, is not limited to learning about traumatic events, and can emerge even in a relatively innocuous computer-based learning task.

In the wake of exposure to a traumatic event, some individuals develop posttraumatic stress disorder (PTSD), including reexperiencing symptoms (intrusive memories, flashbacks) that are triggered by situations or stimuli reflecting aspects of the traumatic event (e.g., Elzinga & Bremner, 2002). A preference towards generalization, a tendency to apply learned responses to stimuli other than those present during learning, may underlie reexperiencing symptoms in PTSD. Overly general memories of traumatic events would then be vulnerable to being triggered by a wide range of stimuli that otherwise would not provoke recall (Tryon, 1998). Thus, individuals with higher levels of PTSD reexperiencing symptoms might show greater generalization, compared to individuals with fewer reexperiencing symptoms, independent of other PTSD symptoms, such as avoidance, numbing, and physiological arousal.

The acquired equivalence (AE) paradigm has previously been used to assess generalization in rats, pigeons and humans (Honey et al., 2010). In this paradigm, subjects learn to map stimuli to consequents (e.g. $S1 \rightarrow C1$, $S2 \rightarrow C2$, $S3 \rightarrow C1$, $S4 \rightarrow C2$). Some stimuli are “equivalent,” i.e., mapped to similar consequents (e.g. $S1$ and $S3$). Later, a subset of stimuli are associated with new consequents (e.g. $S1 \rightarrow C3$, $S2 \rightarrow C4$) and subjects are then tested for generalization (defined as mapping $S3$ to $C3$ and $S4$ to $C4$). Because generalization is not limited to trauma-related conditions, one advantage of this paradigm is the neutral nature of the stimuli. On a computer-based AE task, control groups typically generalize significantly above chance (e.g. Myers et al., 2003). However, patients with Parkinson’s disease (Myers et al., 2003) or depression (Herzallah et al., 2010) have disrupted initial learning but generalize at the same rate as controls. The opposite pattern, i.e., spared learning with below-normal generalization, occurs in alcohol dependence (Máttyáßy et al., 2012) and mild Alzheimer’s disease (Myers et al., 2003). Here, we used the same computer-based AE task to examine generalization processes in a sample of US veterans self-assessed for PTSD symptoms. If reexperiencing symptoms are associated with generalization, those with greater reexperiencing symptoms should show greater generalization in the AE task.

Method

One hundred and fourteen veterans (12 female; age $M = 51.8$ years, $SD = 9.0$; education $M = 13.7$ years, $SD = 2.5$) were recruited from Veterans Affairs New Jersey Health Care System (VA NJHCS) and paid \$40 for participation. Racial breakdown was 82% Black/African-American, 14% White/Caucasian, and 4% Mixed/Other. Sixty-one veterans reported service in one or more military conflicts (30 in Vietnam; 31 in more recent conflicts). Asked about prescription medication, 37 veterans (33%) reported use of antidepressants, 46 (40%) reported other psychoactive medication (usually sleep aids), and the remaining 31 (27%) reported no psychoactive medication use. All participants gave written informed consent and procedures were approved by the VA NJHCS Institutional Review Board.

Participants completed the PTSD Checklist-Military version (PCL-M) to assess PTSD symptoms related to military experiences (Cronbach’s alpha of current sample = .96). A PCL-M total score of 50+ has been shown to be associated with PTSD in military samples (Weathers et al. 1993). The PCL-M also generates subscores for the PTSD symptom categories, based on number of reexperiencing, avoidance/numbing, and hyperarousal symptoms endorsed. Exposure to trauma was not a necessary condition to take part in the study.

Participants also performed a computer-based AE task, previously described by Myers et al. (2003). In brief, during a training phase, subjects learned by trial-and-error to associate cartoon faces with one of two colored fishes (Figure 1A), while receiving corrective feedback (Figure 1B). Some of the faces are equivalent in that they map to the same colored fish. In a final training stage, subjects learn to associate a subset of the faces with different fish. Finally, subjects are tested on all previously-trained face-fish pairs (retention testing), as well as on novel face-fish pairings (generalization testing), with percent errors recorded for both. Most participants ($n = 108$) in the present study also received a test of verbal declarative memory, i.e., the Logical Memory (LM) subtest of the Wechsler Memory Scale-

Revised (Wechsler, 1987), which assessed verbal memory immediately and after a short delay (30 minutes).

Data Analysis

Hierarchical multiple regression was used to examine the ability of PCL-M subscores to account for performance on the AE task (training errors, retention errors, and generalization errors) and the LM task (immediate and delay recall percentile scores). In step 1, demographics (gender, age, education, race), and psychoactive medication use were entered into the model. Because performance in the testing phase of the AE task depends on whether information is initially acquired and retained, training errors was also included as a control variable in analyses of test performance. Similarly, for LM, immediate recall score was entered as a control variable in analysis of delayed recall scores. In step 2, the PCL-M subscore with the largest significant ($\alpha = .05$) beta weight was entered into the model. If none of the PCL-M subscores significantly improved the model, no variables were added in step 2. In no instances did the addition of a second subscore significantly improve a model. There were no missing data and all tests used an alpha of .05 (two-tailed).

Results

Mean PCL-M total score was 46.9 ($SD = 18.5$), with 50 participants (44%) meeting symptom criteria for PTSD. Mean PCL-M subscores were 2.4 ($SD = 2.0$) for reexperiencing symptoms, 3.5 ($SD = 2.7$) for avoidance/numbing symptoms, and 3.1 ($SD = 1.9$) for hyperarousal symptoms. All subscores were significantly correlated with each other (r 's $> .6$, p 's $< .002$); none were correlated with age or education ($-.1 < r < +.2$, p 's $> .50$).

During the training phase of the AE task, subjects averaged 26 errors ($SD = 17.7$). In step one of the hierarchical regression, age ($\beta = .35$, $t[105] = 3.74$, $p < .001$) significantly accounted for training errors. In step two, none of the PCL-M subscores were significant; consequently, none entered into the model. Overall, the model accounted for 18% of the variance ($R = .43$, $F[5, 105] = 4.72$, $p < .001$).

During retention testing, subjects averaged 24% errors ($SD = 19.4$) and, as expected, training errors ($\beta = .77$, $t[104] = 12.29$, $p < .001$) significantly accounted for retention errors. In step 2, no PCL-M subscores were significant. Overall, the model accounted for 67% of the variance ($R = .82$, $F[6, 104] = 34.42$, $p < .001$).

During generalization testing, subjects averaged 37% errors ($SD = 27.6$). Again, training errors ($\beta = .47$, $t[104] = 5.12$, $p < .001$) significantly accounted for generalization errors. This model accounted for 29% of the variance ($R = .54$, $F[6, 104] = 7.23$, $p < .001$). In step 2, the reexperiencing subscore ($\beta = -.23$, $t[103] = 2.72$, $p = .008$) was added to the model and explained an additional 5% of the variation in generalization errors. The final model accounted for 34% of the variance ($R = .58$, $F[7, 103] = 7.63$, $p < .001$; Figure 2A).

Given this finding, we were concerned that there might be a speed-accuracy tradeoff; however, reexperiencing subscore was actually negatively correlated with reaction time

across testing ($r = -.22, p = .019$), and this correlation was significant on retention trials ($r = -.24, p = .011$) but not generalization trials ($r = -.14, p = .129$).

For the LM test, age-adjusted mean percentile scores were 36.3 ($SD = 24.9$) for immediate recall and 33.2 ($SD = 24.2$) for delayed recall. No variables were significant for immediate recall (all $p > .70$). As expected, immediate recall significantly accounted for delayed recall ($\beta = .83, t[99] = 15.04, p < .001$); however, in step two, no PCL-M subscore was significant. Overall, the model accounted for 70% of the variance in delayed recall scores. ($R = .84, F[6, 99] = 38.39, p < .001$; Figure 2B).

The pattern of results did not change when analyses included only males. When the regression analyses were conducted using PCL-M total scores instead of subscores, in no instance was PCL-M significant.

Finally, we classified subjects as “solvers” ($n = 82$) or non-solvers ($n = 32$) based on performing better than chance in the final training stage (i.e. < 24 errors out of 60 possible trials). Solvers and non-solvers did not differ in education, age, gender, race, medication use or PCL-M (Bonferroni-corrected $\alpha = .008$; all $ps > .01$). Results were similar when regression analyses included only solvers.

Discussion

The present study found increased generalization on an AE task in veterans with higher self-reported PTSD reexperiencing symptoms. There was no relationship between any PCL-M subscore and initial training or retention on the AE task, or on tests of immediate or delayed declarative memory recall. The present findings suggest that increased generalization among those with PTSD-related symptoms does not appear to be limited to memories of traumatic or stressful events as it was observed for a purely cognitive associative learning task.

Curiously, Levy-Gigi et al. (2012) used this task to compare trauma-exposed clinically-diagnosed PTSD, trauma-exposed non-PTSD, and non-exposed non-PTSD groups, but obtained quite different results, i.e., decreased generalization in individuals with PTSD, while trauma-exposed non-PTSD subjects were similar to non-exposed subjects. The results may not be as discrepant as they first appear; notably, the generalization results described by Levy-Gigi et al. were bimodal such that nearly 25% of those diagnosed with PTSD made $> 80\%$ errors on generalization trials while the group averaged around 50% errors, suggesting that a subset of the PTSD group generalized quite well. Unfortunately, Levy-Gigi et al. reported only clinical diagnosis, not the number of reexperiencing symptoms. It is possible that those PTSD participants who did well on generalization task might have endorsed a greater number of reexperiencing symptoms than their peers. In fact, a later paper by Levy-Gigi et al. (2014) reported *increased* generalization in patients with clinically-diagnosed PTSD, similar to the findings in our current study.

The current study had several limitations. First, information about medication use and military service was obtained through self-report. Medications and comorbidity of other psychiatric conditions such as anxiety and mood disorders may have influenced learning and generalization and not all participants were necessarily exposed to a traumatic event – while

others may have been exposed to traumatic events that were not necessarily military in nature. Second, because we were interested in the severity of PTSD reexperiencing symptoms, rather than whether participants met all criteria for PTSD, a formal diagnosis of PTSD was not made. Consequently, we cannot confirm whether the pattern of results hold equally for those with clinical or subclinical PTSD. Third, the current study was statistically underpowered to fully examine gender given the low inclusion of females.

Future studies could examine the above issues more fully. In addition, the finding of faster reaction time in those with greater reexperiencing symptom burden was unexpected, and worthy of further investigation; however, it does suggest that the greater generalization in these individuals is not indicative of a speed-accuracy tradeoff. Since the current study includes both trauma exposed and unexposed participants, future studies would benefit from directly comparing these groups. Finally, the stimuli used in the current study were emotionally neutral. It is possible that a tendency to generalize could facilitate the acquisition and transfer of safety conditions. It is also possible that positive or negative-valenced stimuli could differentially impact the tendency toward generalization.

In summary, a current view holds that PTSD reexperiencing symptoms are associated with a process whereby traumatic memories are stored strongly but with minimal detail, which promotes generalization. The present results suggest that this bias for generalization is not limited to traumatic memories but emerges even in the relatively innocuous context of a computer-based associative learning task. Future longitudinal studies would be needed to examine whether such increased generalization emerges in the wake of trauma exposure or with the development of PTSD symptoms, or might be a pre-existing bias that confers risk for developing PTSD upon exposure to a traumatic event.

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(A)

Which fish does this person have?
Use "Left" or "Right" key to choose.

(B)

Which fish does this person have?
Use "Left" or "Right" key to choose.

Correct!

Figure 1.

Example screen events from the acquired equivalence task. (A) On each trial, the subject sees a cartoon face and a pair of colored fish and is asked to guess which color fish that person has. (B) The subject responds by pressing the LEFT or RIGHT key; the chosen fish is circled, and corrective feedback appears. Adapted from Myers et al. (2003).

Figure 2.

Performance on the test phase of the acquired equivalence test (A) and on the Logical Memory test (B) as a function of self-reported PTSD re-experiencing symptoms. (A) The number of re-experiencing symptoms is associated with increased generalization (novel pairs), and is not associated with retention (previously-trained pairs). (B) Performance on the immediate and delayed recall portions of the Logical Memory test (scored as age-adjusted percentile scores) show no association with re-experiencing symptoms.