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Avoidance learning as predictor of posttraumatic stress in firefighters

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ABSTRACT

Background: Avoidance is a well-established maintenance factor in anxiety-related psychopathology. Individuals prone to anxiety show more maladaptive avoidance responses in conditioning paradigms aimed at avoidance learning, which indicates impairments in safety learning. To what extent avoidance learning is associated with posttraumatic stress disorder (PTSD) is still unclear, despite the logical relevance to the symptomatology. In this prospective study, we investigate avoidance learning responses in first responders, a population at high risk for traumatic exposure and thus PTSD development, and studied whether avoidance learning was associated with concurrent and future PTSD symptoms.

Method: Firefighters ($N = 502$) performed an avoidance learning task at baseline assessment in which they first learned that two conditioned stimuli (CS+) were followed by an aversive stimulus (US) and one conditioned stimulus (CS-) was not. After that, they could learn to which CS avoidance of the US was effective, ineffective or unnecessary. Self-reported PTSD symptoms were assessed at baseline, and at 6, 12, 18 and 24 months.

Results: Participants exhibited comparable avoidance patterns to low anxiety individuals from previous studies. Avoidance learning responses were not associated with PTSD symptoms at baseline nor at follow-up.

Discussion: Our study found no evidence that avoidance learning was related to PTSD symptom severity in a high-risk, yet low symptomatic population, nor did it predict the development of PTSD symptoms at a later point in time. Future research should focus on studying avoidance learning in a clinical or high symptomatic sample to further clarify the role of avoidance learning in PTSD development.

1. Introduction

The sheer nature of their job puts first responders (i.e., ambulance personnel, police officers and firefighters) at increased risk for developing trauma-related mental disorders, such as posttraumatic stress disorder (PTSD). Meta-analytic findings report a pooled prevalence rate of around 10 % for PTSD in first responders, and further suggest high comorbidity with depression, anxiety and distress [1,2]. This highlights the necessity for adequate mental health prevention strategies for first responders and a need to understand which factors contribute to the development of PTSD in these high-risk populations.

A factor that might be of great importance is avoidance, which is an obvious and reasonable response to a real threat, but becomes maladaptive when an individual performs avoidance behaviour in absence of a real threat [3]. Avoidance behaviour can be understood in light of learning theories [4,5]. Avoidance is seen as a response to a learned fear association between a conditioned stimulus (CS) and an aversive unconditioned stimulus (US). When confronted with this CS, avoidance behaviour might occur to prevent exposure to the aversive US. Through successful omission of the aversive US, avoidance behaviour becomes negatively reinforced and causes individuals to continue their avoidance behaviour [6]. By avoiding the CS, exposure to disconfirming information (i.e., the US no longer follows the CS) to update the erroneous fear belief (i.e., US follows CS) is prevented and safety learning (CS - no US) is not acquired. Consequently, avoidance leaves the fear association intact.

Also, it has been argued that the non-occurrence of the aversive US due to avoidance behaviour causes the positive feeling of relief, which acts as a positive reinforcer of avoidance behaviour itself [7]. The level of relief is thought to be related to the expectation level that the threat will occur (US-expectancy) [8]. Relief represents the pleasant surprise of

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the non-occurrence of an US, which is assumingly the consequence of the (high) expectancy of the US in combination with the (negative) aversiveness of the US. An individual will report high levels of relief whenever the threat-expectancy is high. When the threat (aversive US) is omitted by the avoidance behaviour, levels of relief and threat-expectancy will decline over time. Interestingly, individual differences in this avoidance-relief mechanism have been related to anxiety proneness ([8]; [7]). Perhaps, such individual differences might also contribute to the development of anxiety-related psychopathology including PTSD symptoms[1] in firefighters.

A typical way of testing these individual characteristics in avoidance learning includes computer-based avoidance conditioning paradigms that in its basics contains an acquisition and avoidance phase (e.g., [9]). Individuals are first exposed to a threat conditioning phase, in which they learn that two stimuli (CS + s) predict an aversive event (US) and one stimulus (CS-) does not. After this acquisition phase, participants receive an option to press a button during each CS presentation in order to prevent a (potential) aversive US from happening (avoidance phase). For one CS+ (CS + avoidable; $CS+_{av}$), pressing the button will indeed lead to successful avoidance of the aversive US, which can be defined as adaptive avoidance. For the other CS+ (CS + unavoidable; $CS+_{unav}$), the aversive US is presented regardless of the use of the avoidance button. During the CS-, pressing the avoidance button does not change the outcome, since CS- is never followed by an aversive US. Avoidance towards the $CS+_{unav}$ and CS- can be defined as maladaptive avoidance. During each CS presentation, US-expectancy is rated and participants are asked to rate their level of relief each time the aversive US remained absent. With this avoidance learning task, several avoidance learning characteristics can be objectified, including total number of avoidance responses, ineffective avoidance (avoidance responses to $CS+_{unav}$) and unnecessary avoidance (avoidance responses towards CS-).

A study that used this avoidance learning task showed that individuals from the general population executed more avoidance responses towards the $CS+_{av}$ and learned to withhold an avoidance response to the CS- and to the $CS+_{unav}$, as these responses were unnecessary or ineffective, respectively [7]. In contrast, individuals prone to anxiety-related symptomatology did not show this avoidance pattern, as they significantly performed more avoidance responses to the $CS+_{unav}$ [8]. Moreover, they reported higher levels of relief after exposure to the $CS+_{av}$ and CS- compared to low trait anxiety individuals. In a study that used a slightly different avoidance conditioning paradigm, individuals prone to anxiety-related symptomatology performed more avoidance response to the CS- during avoidance conditioning [10]. In sum, individuals prone to anxiety-related symptomatology seem to focus on potential US outcome rather than considering the probability of the US occurrence. Hence, preventing them from learning new associations with the CS (i.e., CS - no US), which may indicate safety learning impairments in these individuals, potentially contributing to the development of anxiety-related psychopathology.

As avoidance plays an important role in anxiety-related disorders [11], it is of interest to investigate avoidance learning in clinical samples and to investigate its predictive value in a high-risk population for anxiety-related disorders, including PTSD. It is known that patients with anxiety disorders experience safety learning impairments during fear acquisition, as they report elevated levels of fear to a CS- [12]. The first clinical study using the same avoidance learning task has been conducted in patients with anxiety-related disorders now [13]. Although the results are too preliminary to draw any firm conclusions yet, they indicate increased maladaptive avoidance responses in patients with anxiety-related disorders compared to healthy controls. In sum, there is some evidence that maladaptive avoidance tendencies are related to anxiety-proneness, but more research is needed to further our understanding of its role in anxiety-related psychopathology and the development of anxiety-related psychopathology.

The first aim of the current study is to investigate the relation between avoidance learning and posttraumatic stress symptomatology in a high-risk sample of firefighters. Using cross-sectional data, we hypothesized that PTSD symptoms are associated with (1) higher overall avoidance response frequency, (2) more ineffective avoidance responses, and (3) more unnecessary avoidance responses. Besides avoidance responses, the association between PTSD symptoms, relief and US-expectancy will be investigated to gain more insight into potential mechanisms driving avoidance behaviour. Previous studies have highlighted the importance of fear conditioning studies with a prospective design in high-risk PTSD populations (e.g., [14]). Combined with the evidence of altered avoidance learning in anxiety-prone individuals, it seems fruitful to investigate the potential predictive value of avoidance learning in the development of PTSD. Therefore, the second aim of this study is to investigate the potential predictive value of avoidance learning in the development of PTSD. For this aim, 2-year prospective data will be used to test whether aforementioned avoidance tendencies predict PTSD symptoms. This will test whether avoidance learning reflects a vulnerability factor for PTSD. If avoidance learning alternations would be a predictor of PTSD symptom development, this might have the potential to be targeted in primary prevention of PTSD.

2. Method

2.1. Participants

In the summer of 2017, 529 participants currently employed as firefighter in the Netherlands (The Netherlands Fire Service) enrolled in this study. Twenty-seven participants failed to complete the baseline assessment which included the avoidance learning task, as these participants were called out to respond to an emergency situation or have stopped prematurely because of the unpleasantness of an aversive stimulus during one of the experimental conditioning tasks. Only participants who completed the avoidance learning task were included in the analyses.

The final sample of 502 participants (95 % male) had a mean age of 39.8 years (SD = 9.95). Most participants were married (51.4 %) or cohabiting (26.1 %). Some were single (14.3 %), living apart together (7.4 %) or were widowed (0.8 %). Their highest attained education level was elementary (0.4 %), secondary (84.9 %), or higher education (14.7 %). Participants worked as a professional firefighter (42.8 %), volunteer (26.3 %) or combined both functions (30.9 %). Participants worked on average 15 years as firefighter (SD = 9.31) and had the following ranks: Engineer (45.2 %), Captain (28.9 %), Firefighter (15.5 %), Battalion Chief (4.8 %), Trainee (3.2 %), other functions (1.6 %) or Division Chief (0.8 %).

Follow-up assessments were administered every half year up to two years. Response rates on the self-report PTSD questionnaire were 64.3 % (n = 323) at first follow-up (6 months), 45.8 % (n = 230) at 12 months, 42.6 % (n = 214) at 18 months and 38.9 % (n =195) at 24 months. Non-response at follow-up assessment was not related to PTSD symptom severity at baseline, $t(500) = 1.097$, $p = .273$. Response rates on the clinical interview in follow-up assessment were higher: 71.1 % (n = 357) at 12 months and 62.7 % (n = 315) at 24 months. This study is part of a larger 5-year prospective study on mental resilience in firefighters and was approved by the Ethical Committee of Psychology of the University of Groningen.

[1] As learning theories have been used to understand the development of anxiety disorders and PTSD, previous studies on anxiety disorders included participants with PTSD and PTSD is no longer classified as an anxiety disorder in the DSM-5 (APA, 2013), we use the word anxiety-related disorders to refer to both anxiety disorders and PTSD.

2.2. Procedure

Eleven of the twenty-five safety regions in the Netherlands expressed their willingness to participate in this study. After providing written information about the study, a team of researchers visited fire stations within each participating safety region in the summer of 2017. Firefighters were informed once again about the study via written and oral information and were told that they could withdraw at any time during this 5-year prospective study. It was also emphasized that participation was strictly voluntary without financial compensation and refusal to participate had no negative consequence. After providing written informed consent, the baseline assessment started. Participants filled out a battery of online self-report questionnaires for approximately one hour. After that, several computer-based conditioning tasks were individually administered for one hour in the presence of a research assistant. Measurements that are beyond the scope of this study will not be reported here.

Participants were approached every six months for follow-up assessments over the course of two years. Follow-up assessment after 6 months (T1) and 18 months (T3) consisted of online questionnaires only (including the PTSD Checklist for DSM-5, PCL-5). At 12 months (T2) and 24 months (T4) follow-up, additional clinical interviews (i.e., MINI International Interview, MINI-Plus) by telephone were conducted by trained research assistants.

2.3. Avoidance learning task

The task consisted of two phases: a Pavlovian phase in which participants could learn the associations between the three CSs and the aversive US (threat-expectancy learning), and an avoidance phase in which participants could learn the association between the avoidance button and the actual prevention of the aversive US (avoidance conditioning). Prior to the Pavlovian phase, participants were instructed about the expectancy-ratings and the relief-rating scale, and they were told which colours would be followed by the aversive US and which colour not. Participants received these instructions about the CS-US contingencies in order to speed up learning during the Pavlovian phase, as we were only interested in the second, avoidance phase.

The Pavlovian phase consisted of 2 presentations of each CS. Two of the three CSs were immediately after CS offset followed by the aversive US on each presentation (CS+; 100 % reinforcement rate), while the third was never followed by the aversive US (CS-). One second after each CS onset, the rating-scale appeared. The CS remained on screen until the participant clicked the scale (with a 300 ms delay). The aversive US was presented immediately after offset of a CS+ . The CS- was followed by the relief-rating scale after a delay of 2 s. The scale remained on the screen until clicked by the participant (with a 300 ms delay).

Prior to the avoidance phase, the participant received additional instructions about the use of the avoidance button. They were told that they would sometimes be able to prevent the aversive US by using the red button, and that it was their task to figure out when they could prevent the aversive US. They were also warned that the red button would only appear for 2 s.

The avoidance phase consisted of 12 presentations of each CS, divided into two blocks of 6 presentations. During each CS presentation, the red button appeared one second after CS onset and remained on screen for 2 s (irrespective of an avoidance response). The expectancy-rating scale appeared 500 ms after disappearance of the red button. The CS and the scale disappeared 500 ms after the participant clicked the scale. One CS+, the unavoidable CS+ ($CS+_{unav}$), was always followed by the aversive US, irrespective of button clicking. The other CS+ was the avoidable CS+ ($CS+_{av}$) and was not followed by the aversive US when the red button was clicked. When no aversive US followed the CS (avoided $CS+_{av}$ and the CS-), the relief-rating scale appeared 2 s after CS offset. In between the two blocks of 6 presentations of each CS, two $CS+_{av}$ presentations were added during which clicking the red button had no effect (temporarily unavoidable). These presentations were inserted to create uncertainty in the task and investigate the re-learning of the association between $CS+_{av}$ and US omission in the second block. Throughout the entire task, inter-trial intervals were set at 2 s.

2.4. Measures

2.4.1. Posttraumatic stress symptoms

The Dutch version of the PTSD Checklist for DSM-5 (PCL-5) was used to assess PTSD symptom severity [15]. This self-report questionnaire consists of 20 items, representing PTSD symptoms according to the DSM-5 [16], which are rated on a 0 (*Not at all*) to 4 (*Extremely*) scale. Reliability and validity of the original measure is good [17]. Psychometric properties of the Dutch translation are currently studied. Cronbach's alphas in the current sample were excellent (T0: $\alpha = .927$, T1: $\alpha = .938$, T2: $\alpha = .946$, T3: $\alpha = .929$, T4: $\alpha = .954$).

The Dutch version of the Mini International Neuropsychiatric Interview Plus (MINI-Plus), version 5.0.0., was used to determine if participants met the criteria of a PTSD diagnosis [18]. This semi-structured clinical interview assesses various common psychiatric disorders according to the DSM-IV criteria [19]. Reliability and validity of the original interview is good [20].

2.4.2. Traumatic and impactful work-related events

The Dutch version of the Life Events Checklist for DSM-5 (LEC-5) was used [21]. This self-report questionnaire contains 16 potentially traumatic events, which can be rated by (a) happened to me, (b) witnessed it, (c) learned about it, (d) part of my job, (e) not sure, and (f) does not apply. To ensure the rated experiences met the A criterion of traumatic events according to the DSM-5 [16], an item was rated as present when answer option a), b) or d) was chosen.

To assess impactful work-related experiences specific for firefighters, a questionnaire was created in close collaboration with firefighters. This questionnaire contains 21 stressful events that are common in the work of a firefighter, such as 'resuscitation of a child' or 'deceased adult by fire'. Participants were asked to answer if they had experienced this event (yes/no).

2.4.3. Avoidance learning task

The computer-based avoidance learning task was programmed with the Affect4 Software, which also recorded the outcome variables of this task [22].

2.4.3.1. Conditional stimuli. Three different colours served as conditional stimuli (red, blue, and yellow). These colours were embedded in a picture of an office room with a desktop lamp (for a depiction of the CSs, see [7]). After one second presentation of the desktop lamp unlit, it would take on one of the three colours.

2.4.3.2. Unconditional stimulus. The aversive unconditional stimulus was a combination of a 500 ms negative picture[2] from the international affective picture system (IAPS; [23]) and a 2 s female scream[3] of 90 dB (IADS; [24]). On each trial, a negative picture was drawn randomly from a pool of 12 negative pictures (snake, spider, aggressive dog, gun, dirty toilet, crying child, …). Perceived aversiveness of the US was rated after the task on a 0 ("neutral") to 10 ("very unpleasant") scale.

2.4.3.3. Avoidance responses. A red button superimposed on the room picture signalled the availability of the avoidance response, by clicking the red button using the computer mouse. The duration of the red button

[2] 1050 (snake), 1200 (spider), 1280 (rat), 1300 (Pitbull), 1930 (shark), 2800 (sad child), 6260 (aimed gun), 6350 (knife attack), 9320 (vomit), 9402 (mob), 9570 (animal cadaver), and 9582 (dental exam) from the IAPS system

[3] 277 (female scream) from the IADS system

was always 2 s. Whether or not the button was clicked during the 2 s was registered by the software.

2.4.3.4. Expectancy-ratings. During each CS presentation, the question "To which degree do you expect a negative picture?" and an 11-point rating scale appeared at the bottom of the computer screen that ranged from 0 ("certainly no picture with scream") over 5 ("uncertain") to 10 ("certainly picture with scream"). Participants operated the scale by moving the cursor of the computer mouse to the desired position and clicking the left mouse-button.

2.4.3.5. Relief-ratings. Whenever a CS presentation was not followed by the aversive US, the question "How relieved were you that there was no picture" and an 11-point rating scale appeared in the middle of the screen that ranged from 0 ("little relief") over 5 ("moderate relief") to 10 ("ample relief"). Participants operated the scale by moving the cursor of the computer mouse to the desired position and clicking the left mouse-button.

2.5. Statistical analyses

All analyses were performed in IBM SPSS version 26. Various descriptive statistics, including PTSD diagnosis have been analysed. To check whether acquisition of threat was successful, a paired sample *t*-test was run. Repeated measures analyses of variance (RM-ANOVAs) were run to investigate avoidance responses, US-expectancy and relief ratings per CS during the avoidance conditioning phase (2 (block) x 3 (CS)). Averages of these variables were used to prevent listwise deletion due to missing values and to convert the binary avoidance response variable into a continuous variable (i.e., [7]).

The associations of avoidance response frequency, avoidance response to $CS+_{unav}$ (ineffective avoidance) and avoidance response to CS- (unnecessary avoidance) with PTSD symptoms at baseline (T0) were investigated using linear regression models. Since avoidance response is inherently influenced by the costs - in this study the perceived averseness of the US - US-aversiveness rating was included as covariate. Change scores were calculated using the means of block 1 and block 2, for both US-expectancy and relief rates. These scores were entered the linear regression models. To explore whether avoidance learning predicted subsequent development of PTSD symptoms, the associations between the highest PCL-5 score at any follow-up measurement and avoidance response frequency, ineffective avoidance response and unnecessary avoidance response were investigated with linear regression analysis models. To control for PTSD symptom level at baseline, this was included as covariate, next to US-aversiveness rating.

3. Results

3.1. Sample characteristics

Eleven participants (2.2 %) met the clinical cut-off point according to the PCL-5 (cut-off score ≥ 33; [17]) at baseline, 4 participants at T1 (1.2 %), 2 participants on T2 and on T3 (0.9 %), and 4 participants on T4 (2.1 %). Mean PTSD symptom severity ranged between 5.78 (SD = 8.35) at baseline and 3.47 (SD = 7.90) after two years. Mean US-aversiveness in the avoidance learning task was 4.39 (SD = 2.69).

A total of 386 participants (76.9 %) completed at least one self-report PTSD questionnaire during follow-up and were included in the prospective analyses. From this prospective sample, 78.2 % of participants (n = 302) completed the clinical interview at one year and 69.7 % of participants (n = 269) at follow-up after two years. Results from these clinical interviews revealed that 4 participants (1.3 %) from this sample fulfilled DSM-IV diagnostic criteria for a current PTSD diagnosis after one year and 3 participants (1.1 %) after two years.

Exposure to a criterion A traumatic event was high, with 99.3 % of participants reporting lifetime exposure after one year and 98.9 % of participants after two years according to the clinical interview. At baseline, participants experienced on average 7.42 different types of traumatic events (SD = 2.67), with fire or explosion (95.8 %) and accident (95.6 %) being most prevalent. Moreover, participants reported on average 11.12 different impactful work-related events (SD = 4.11) at baseline, such as 'person trapped in vehicle' (92.0 %), 'suicide of an adult' (82.5 %) and 'recovering a corpse' (75.1 %).

3.2. Threat-expectancy learning

Thirty participants (6%) reported higher US-expectancy levels during CS- presentations than on both CS+ presentations, indicating insufficient understanding of the instructions of the avoidance conditioning task. For 4 participants (0.8 %) we were unable to calculate US-expectancy scores during threat-expectancy learning due to missing US-expectancy rates to $CS+_{unav}$. Using a threat-expectancy acquisition criterion (i.e., mean US-expectancy to CS+s is higher than to CS-), 468 participants (93.2 %) could be classified as learners. Thus, those identified as non-learners (6%) failed to show a higher mean US-expectancy to CS+s compared to the mean US-expectancy to CS-, despite clear instructions of which CSs would be followed by an aversive US and which CS would not be followed by an aversive US. Nevertheless, all analyses are based on the whole sample (N = 502), including the non-learners (6%) and 0.8 % of participants with missing US-expectancy rates, as exclusion of participants in fear conditioning studies is not recommended [25].

Threat-expectancy learning was successful, evidenced by significant differences in US-expectancy ratings per CS. US-expectancy was significantly higher to $CS+_{unav}$ than to $CS+_{av}$ ($t(497) = 4.15, p < .001$) and CS- ($t(497) = 42.60, p < .001$). US-expectancy to $CS+_{av}$ was significantly higher than to CS- ($t(501) = 39.17, p < .001$) (see Fig. 1A). Relief during the acquisition phase was only rated during CS- presentations and was as expected, low ($M = 3.7$, $SD = 3.0$). These results indicate that participants understood the instructions and successfully learned which CSs predicted an aversive US and which one did not.

3.3. Avoidance conditioning

Mean avoidance responses during avoidance conditioning was 19.67 (SD = 11.04, range: 0–36). Participants avoided on average 7.71 times the $CS+_{unav}$ (SD = 4.32, range: 0–12) and 3.42 times the CS- (SD = 4.79, range: 0–12) (see Fig. 2 for scatterplots of avoidance responses). Avoidance responses differed significantly per CS, $F(1.55, 770.30) = 404.64$, $p < .001$, and over blocks, $F(1, 496) = 4.06$, $p = .04$. The CS*blocks interaction was also significant, $F(1.99, 990.84) = 5.62$, $p < .01$. Post-hoc analysis showed that participants performed significantly more avoidance responses in block 1 to $CS+_{av}$ compared to $CS+_{unav}$ ($t(497) = 4.34, p < .001$), and CS- ($t(496) = 22.23, p < .001$). Number of avoidance responses to $CS+_{unav}$ was also significantly higher than to CS- in block 1 ($t(496) = 20.38, p < 0.001$). This pattern remained the same in block 2: avoidance responses to $CS+_{av}$ was significantly higher compared to $CS+_{unav}$ ($t(501) = 6.30, p < .001$) and CS- ($t(501) = 20.91, p < .001$). Avoidance responses to $CS+_{unav}$ remained significantly higher compared to CS- ($t(501) = 17.79, p < .001$). Additionally, there were no significant differences in avoidance response over blocks to $CS+_{av}$, $t(497) = 0.94$, $p = 0.35$ and CS-, $t(496) = 0.59$, $p = .56$, but number of avoidance response significantly declined over blocks to $CS+_{unav}$ ($t(497) = 3.29, p < 0.01$) (see Fig. 1B).

US-expectancy significantly differed per CS, $F(1.88, 941.90) = 1268.60$, $p < 0.001$, and over blocks, $F(1, 501) = 44.62$, $p < 0.001$. The interaction effect (CS*blocks) was also significant, $F(1.77, 888.42) = 37.93$, $p < 0.001$. Post-hoc analysis showed that US-expectancy to $CS+_{unav}$ was significant higher compared to $CS+_{av}$ and CS- in both block 1 ($t(501) = 17.46, p < .001$, and $t(501) = 43.05, p < 0.001$, respectively) and in block 2 ($t(501) = 17.61, p < .001$, and $t(501) = 47.52, p < 0.001$,

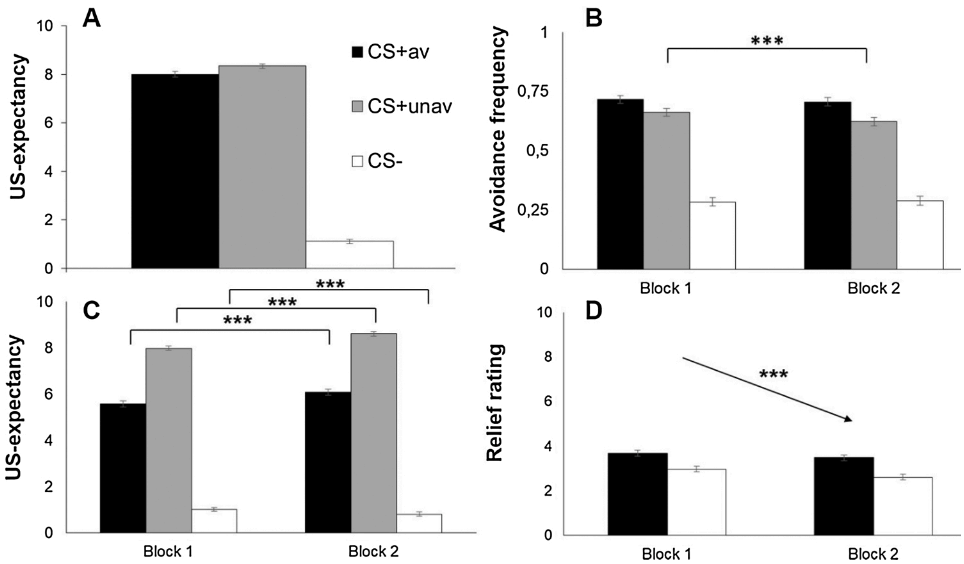

Fig. 1. A-D. Note. Only block effects have been highlighted in these figures, Errors bars represent standard errors of the mean, *** $p < .001$. Fig. 1A: US-expectancy was higher in CS+s, indicating successful threat-expectancy conditioning. Fig. 1B: During avoidance conditioning, avoidance response was stimulus-specific and declined to CS$+_{unav}$ over blocks. Fig. 1C: During avoidance conditioning, US-expectancy was stimulus specific, increased to CS$+_{av}$ and CS$+_{unav}$ and declined to CS- over blocks. Fig. 1D: Relief was stimulus-specific and decreased to both CS$+_{av}$ and CS- over blocks.

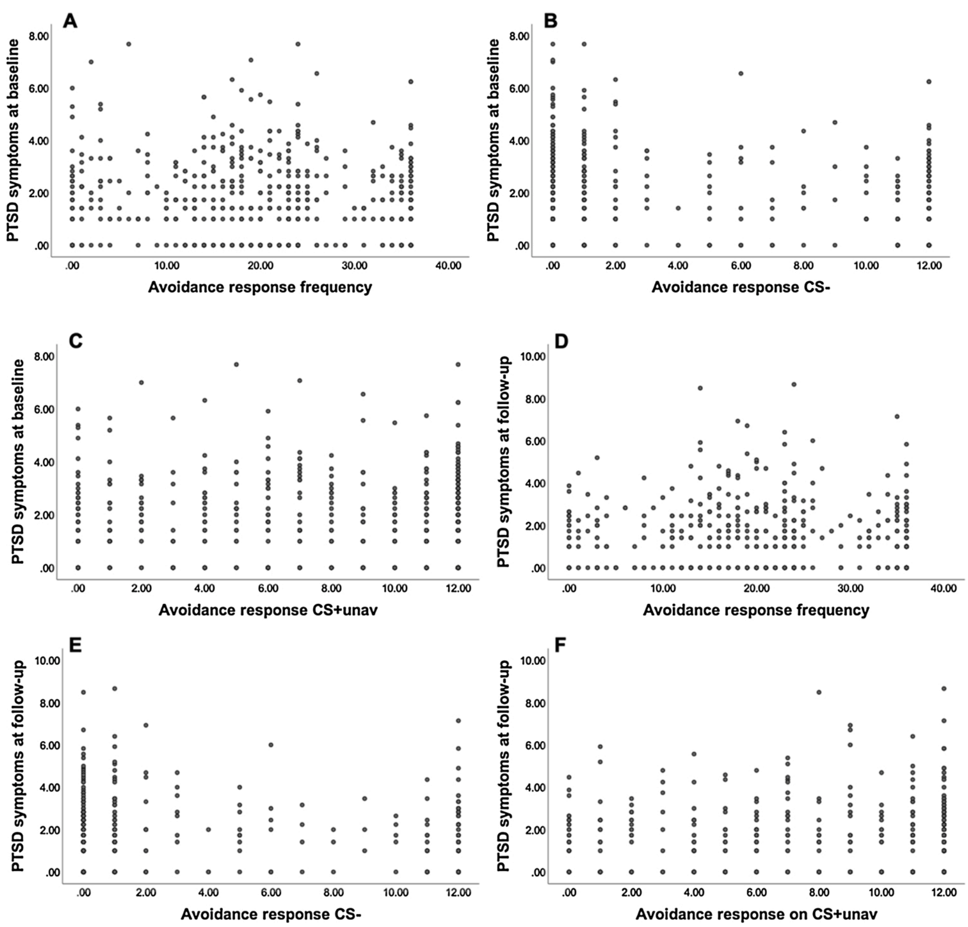

Fig. 2. A-F Note. Scatterplots depict the distribution of avoidance responses related to PTSD symptoms at baseline (A-C) and avoidance response related to the highest PTSD symptom level at follow-up (D-F). The dependent variables PTSD symptoms at baseline at highest PTSD symptoms at follow-up were square root transformed.

respectively). In both blocks US-expectancy to CS$+_{av}$ was significantly higher compared to CS- ($t(501) = 26.79, p < 0.001$ and $t(501) = 31.58, p < .001$). Moreover, post-hoc analysis showed a significant increase of US-expectancy over blocks to CS$+_{av}$ ($t(501) = 5.03, p < .001$) and CS$+_{unav}$ ($t(501) = 8.91, p < .001$), and a significant decline over blocks to CS-, $t(501) = 5.00, p < 0.001$ (see Fig. 1C).

Relief ratings differed per CS, $F(1, 407) = 30.44, p < .001$, and changed over blocks, $F(1, 407) = 130.09, p < 0.001$. Also, the interaction effect (CS*block) was significant, $F(1, 407) = 6.29, p = 0.01$. Post-hoc analyses showed significantly higher levels of relief to CS$+_{av}$

compared to CS- on both blocks ($t(444) = 9.81$, $p < .001$, and $t(415) = 10.86$, $p < .001$, respectively) and showed significant decline of relief to both $CS+_{av}$, ($t(407) = 3.44$, $p < .01$, and CS-, $t(501) = 6.85$, $p < .001$, over blocks (see Fig. 1D).

3.4. Avoidance learning and PTSD symptoms

Square root transformation was applied to minimize the right-sided skew in PCL-5 scores. Linear regression models showed no association between either of the avoidance responses and baseline PTSD symptoms. That is, avoidance response frequency, avoidance response to CS- (unnecessary avoidance), nor avoidance response to $CS+_{unav}$ (ineffective avoidance) was significantly associated with baseline PTSD symptoms. Also, changes in US-expectancy and relief ratings of either CS were not significant associated with baseline PTSD symptoms. In all aforementioned linear regression models, US-aversiveness rating appeared to be significant associated with baseline PTSD symptoms (see Table 1).

Highest PCL-5 score on follow-up appeared to be non-normally distributed. A squared root transformation was conducted to make the distribution less skewed. Linear regression models showed that both avoidance responses at baseline assessment and US-aversiveness rating did not predict subsequent PTSD symptoms. PTSD symptoms at baseline did predict PTSD symptoms at a later point in time (see Table 2). In conclusion, avoidance response at baseline did not predict PTSD symptoms at a later point in time.

Table 1
Association between PTSD symptom at baseline and predictors.

Predictor	*t*	*p*	*B*	*F*	df	*p*	R^2
				13.55	2,499	<.001	.052
Avoidance response frequency	1.53	.13	−0.009				
US-aversiveness rating	5.11	<.001	0.129				
				12.99	2,499	<.001	.049
Avoidance $CS+_{unav}$	1.13	.26	−0.018				
US-aversiveness rating	5.07	<.001	0.128				
				12.70	2,499	<.001	.048
Avoidance CS-	0.85	.39	−0.012				
US-aversiveness rating	5.00	<.001	0.126				
				13.39	2,499	<.001	.051
Change in US-expectancy $CS+_{av}$	1.43	.15	−0.042				
US-aversiveness rating	4.93	<.001	0.124				
				12.37	2,499	<.001	.047
Change in US-expectancy $CS+_{unav}$	0.32	.75	−0.014				
US-aversiveness rating	4.95	<.001	0.125				
				12.34	2,499	<.001	.047
Change in US-expectancy CS-	0.19	.85	0.014				
US-aversiveness rating	4.96	<.001	0.125				
				10.10	2,405	<.001	.048
Change in relief $CS+_{av}$	0.44	.66	−0.026				
US-aversiveness rating	4.46	<.001	0.124				
				12.45	2,499	<.001	.048
Change in relief CS-	0.49	.63	−0.029				
US-aversiveness rating	4.99	<.001	0.126				

4. Discussion

It is well established that avoidance plays an important role in anxiety-related disorders, but studies investigating how avoidance is learned in relation to anxiety-related psychopathology remain scarce, leaving questions about the role of avoidance learning in the development of anxiety-related disorders unanswered [4]. Answers to these questions are important, as they may increase our knowledge about the development of anxiety-related disorders, such as PTSD. This may subsequently help to improve primary prevention in populations that are at high risk for traumatic exposure and thus development of PTSD. This study investigated avoidance learning in a high-risk population of firefighters via an experimental avoidance conditioning paradigm and examined whether avoidance learning was associated with concurrent posttraumatic stress symptomatology and predictive of future posttraumatic stress development.

General analysis of the performance on the avoidance learning task showed that avoidance responses were stimulus-specific: participants performed most avoidance responses towards the $CS+_{av}$, avoidance responses towards the $CS+_{unav}$ ceased over blocks and few avoidance responses were performed to the CS-. In other words, participants learned to perform more adaptive avoidance behaviour, stop their ineffective avoidance, and to withhold unnecessary avoidance, similar to the performance of low-anxiety individuals in previous studies [7,8]. Relief ratings and US-expectancies per CS corresponded with previous findings and suggested a learning effect: higher initial relief and US-expectancy rates to CS+s compared to CS-, a decline of relief in both $CS+_{av}$ and CS- and a decline of US-expectancy to CS- over blocks. Participants learned which CS predicted an aversive US and subsequently reported less relief and lower US-expectancy to CSs that were not followed by an aversive US. In line with learning theories, levels of US-expectancy increased over blocks to $CS+_{unav}$, as participants learned that the aversive US was never avoidable for this CS. Contrary to our expectations, US-expectancy also increased to $CS+_{av}$. Closer examination of the trial-by-trial data revealed that US-expectancy to $CS+_{av}$ declined over block 1, but increased at the beginning of block 2. This increase can be explained by the two $CS+_{av}$ presentations that were added in between the two blocks, during which the avoidance button was temporarily unavoidable and thus led to an aversive US, regardless of the avoidance response.

Analyses testing our first main research question, whether avoidance learning was associated with posttraumatic stress symptomatology, showed that avoidance response frequency, ineffective avoidance and unnecessary avoidance were not associated with PTSD symptoms at baseline assessment, nor did it have an association with changes in relief and US-expectancy ratings. US-aversiveness rating did have an association with PTSD symptoms at baseline, indicating that individuals who rated the US as more aversive experienced more PTSD symptoms. Testing our second main research question, using prospective analyses, showed that none of the avoidance learning characteristics predicted future PTSD symptoms. Only PTSD symptoms at baseline predicted PTSD symptoms at follow-up. Interestingly, US-aversiveness rating was correlated with PTSD symptoms at baseline, but did not predict PTSD symptoms in the prospective analyses in which PTSD symptoms at baseline was also included as predictor. These two predictors might have explained the same variance, with PTSD symptoms at baseline as stronger predictor. The association between PTSD symptoms at baseline and US-aversiveness rating might be explained by hyperarousal symptoms, which is part of the symptomatology of PTSD. Individuals with more severe PTSD symptoms might therefore react more strongly to the aversive US. Future studies could therefore consider including an individually adjustable aversive US.

Aforementioned results contrast previous research that found an association between avoidance responses, relief, and anxiety proneness characteristics (e.g., trait anxiety, distress tolerance and intolerance of uncertainty) [8]. Discrepancies between findings could possibly be

Table 2
Association between PTSD symptoms over time and predictors.

Predictor	t	p	B	F	df	p	R^2
				50.31	3,382	<.001	.283
Avoidance response frequency	0.54	.59	0.004				
US-aversiveness rating	1.07	.29	0.029				
Baseline PCL-5 score	11.78	<.001	0.570				
				50.42	3,382	<.001	.284
Avoidance $CS+_{unav}$	0.72	.47	0.012				
US-aversiveness rating	1.04	.30	0.028				
Baseline PCL-5 score	11.79	<.001	0.570				
				50.23	3,382	<.001	.283
Avoidance CS-	0.34	.73	−0.005				
US-aversiveness rating	1.14	.26	0.030				
Baseline PCL-5 score	11.73	<.001	0.567				

attributed to different sample characteristics. Our sample of firefighters may represent a relatively resilient sample and therefore differ substantially from a student sample. The low levels of self-reported PTSD symptoms, the limited number of firefighters meeting clinical PTSD cut-off at baseline (2.2 %), and the single individuals meeting diagnostic criteria of PTSD at follow up (1.1 %–1.3 %) are indicative of this. Although meta-analytic findings report increased current PTSD prevalence rate of 10 % among first responders worldwide, their findings also show large heterogeneity among rescue workers, with a variety of variables influencing PTSD prevalence, including geographical location (i.e., Europe less than Asia, primarily due to major natural disaster occurrence) and type of rescue work (i.e., firefighter less than ambulance personnel) [1]. Research has also shown that first responders may be better adept to handle traumatic exposure due to initial selection procedures, training and organizational support [26]. It could be argued that the current sample might not have been exposed to traumatic events, resulting in the low PTSD prevalence rate. With high rates of exposure to a traumatic event (98.9–99.3 %), this seems highly unlikely. The relatively low PTSD prevalence rate resembles rates found in other high-risk samples in the Netherlands, including deployed soldiers [13, 27].

To our knowledge, this is the first study that investigated avoidance learning as predictor for PTSD. Such prospective studies are of great importance, as they provide insight in existing vulnerability factors. This in turn can benefit primary prevention efforts. The current study has some limitations: First of all, PTSD symptoms were rated by self-report questionnaires and may have been underreported. First responders might be more prone to trivialize potential mental problems out of fear for negative professional consequences [28]. Also, stigma for mental health issues in first responders is quite common [29]. Second, our sample suffered from considerable dropout at follow-up (23.1 %). Although this is almost inherent to prospective studies, it may have caused selection bias in the follow-up sample. Third, this study includes the use of self-report ratings alone in the avoidance paradigm, it would be interesting to also include psychophysiological measures in future studies. Fourth, this study includes a relative simplistic avoidance learning task. It has been suggested that more ambiguous conditioning tasks that contain more uncertainty might enhance the expression of individual differences and seem more valuable for understanding psychopathology, such as PTSD vulnerability [30]. A consideration for future studies would be to include a less simplistic and more ambiguous task to test avoidance learning [31]. The strengths of the current study include the large sample, the prospective design and control for PTSD symptoms at baseline.

In sum, the current study showed that avoidance learning was not related to PTSD symptom severity in a high-risk, yet low symptomatic population, nor did it predict the development of PTSD symptoms at a later point in time. These results question the role of avoidance learning in the development of PTSD in a high-risk population. Future research should focus on studying avoidance learning in clinical or high symptomatic samples, as it is currently unclear which role avoidance learning has in the development of anxiety-related disorders in various samples. A better comprehension of avoidance learning can potentially contribute to our knowledge about the development of anxiety-related disorders and might in turn help to tailor treatment in the future. Furthermore, it would be interesting for future studies to identify other potential vulnerability factors for the onset of PTSD in first responders.

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CRediT authorship contribution statement

Rick de Haart: Methodology, Formal analysis, Writing - original draft. **Joanne Mouthaan:** Methodology, Investigation. **Bram Vervliet:** Methodology, Software, Resources. **Miriam J.J. Lommen:** Conceptualization, Investigation, Methodology, Supervision, Project administration.

Declaration of Competing Interest

The authors report no declarations of interest.

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