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Research paper

Ready and waiting: Freezing as active action preparation under threat

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HIGHLIGHTS

- Freezing is an essential defensive response often studied using passive viewing tasks.
- We developed a shooting task manipulating threat and action preparation.
- Freezing was operationalized using heart rate and body sway measurements.
- Freezing was found to be strongly related to the ability to respond.
- Freezing is a state of active preparation for a possible fight/flight response.

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ABSTRACT

Freezing is a defensive response characterized by rigidity and bradycardia, but it is unclear whether it is a passive versus active preparatory state. We developed a shooting task in which preparation and threat were manipulated independently: Participants were either helpless or able to respond to a possible upcoming attack, and attacks were either associated with an electric shock or not. Essentially, a purely anticipatory preparatory period was used during which no stimuli occurred. Freezing was assessed during this period. In addition to heart rate, body sway was measured, using a stabilometric force platform. The efficacy of the threat manipulation was confirmed via self-report. The ability to prepare led to decreases in heart rate and postural sway, while threat led to decreased heart rate. Further, exploratory analyses suggested that aggressive participants showed reduced initial freezing for threatening opponents, but increased postural freezing when armed. The results suggest that freezing may involve active preparation. Relations to results in passive viewing tasks are discussed.

Freezing is a defensive response that occurs on the detection of relatively distant threat, in which an animal is immobile, shows reduced heart rate, and is highly vigilant towards the threatening stimulus [1–3]. In contrast to passive tonic immobilization ("playing dead"), freezing in the sense of "attentive immobility" may actively prepare the animal for further defensive responses [4–6], as suggested by increased rather than decreased startle responses during freezing [7,8]. Freezing is preserved in humans as shown, first, by self-report in simulated [9] and actual threatening or traumatic situations [10–12]. Second, freezing has been experimentally studied using physiological measures: Aversive stimuli evoking fear of physical injury [13–16] as well as social threat [17] are associated with freezing as measured via reduced heart rate and body sway. Freezing has recently been shown to evoke a shift in the perception of stimuli with low versus high spatial frequency [18], which was interpreted in terms of freezing being a preparatory state aimed at optimally countering threat.

Despite this possible functional role of freezing as active and attentive preparation, studies of freezing in humans have as yet focused on passive viewing tasks. Therefore, the current study was designed to study freezing in an active context. We developed a shooting task with trials in which participants were confronted with either a safe or a threatening opponent, who performed an attack (drawing a gun and subsequently shooting) or a non-attacking action (holding up a phone) after a preparation interval. Threat was manipulated by having a successful attack by the threatening opponent be followed by an electric shock. Active versus passive preparation was manipulated by providing the participant with a gun or leaving them unarmed. Being armed allowed the participant to shoot the opponent before his attack was completed,

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if the response was made quickly enough after the initiation of the enemy's attack. This enabled us to study the time course of freezing during the preparation interval as a function of threat and response availability. This is somewhat similar to an interesting study published recently, in which participants could or could not actively avoid an approaching threat [19]. Freezing was found to increase when subjects could not actively avoid threat. However, while in that study task-relevant stimulus changes occurred during the period in which freezing was assessed, in the current study the preparation interval does not involve any dynamic changes in stimuli: Subjects are in a "pure" state of anticipation, and only at the end of the preparation interval does any further stimulus event occur. This enables us to focus on anticipatory activity unrelated to the occurrence of salient stimulus changes. In the Löw et al. study, a possible interpretation of the threat-related physiological changes is that they occurred due to stimulus changes. Thus, an essential difference between the studies is that the current study assessed the specific psychophysiological and bodily effects during the anticipation of a threat stimulus, rather than in response to the changing stimulus properties.

The current study is aimed at the study of freezing in the context of an anticipatory period, during which no stimulus changes occurred but subjects could prepare to respond to an upcoming possible attack. Freezing was assessed while participants were performing the shooting task, under four conditions defined by two factors: Action preparation (Active versus Passive conditions) and Threat (Threat versus Safe conditions). In addition to heart rate, body sway was measured, using a stabilometric force platform. A secondary aim of the study was to extend the literature on relationships between freezing and individual differences from the passive to the active context; to this aim we explored correlations between measures of freezing and anxiety and aggression. Individual differences in freezing have been shown to be related to individual differences in human research on freezing. More trait anxious participant show increased freezing when confronted with angry faces [17], and participants with experience of traumatic life events exhibit more freezing in response to aversive stimuli [14]. We aim to extend these results in the current study. However, it is not certain that freezing is necessarily related to anxiety specifically. As described above, freezing is a functional defensive response that may marshal resources to respond to threat in general, not just "cower in fear". To further typify what freezing is and how it should be conceptualized, we therefore also tested relationships between measures of freezing and aggression. Taken together, the current study thus allows a first comparison of two different views of freezing in the context of preparation under threat: freezing as a passive state more likely to be shown by anxious participants in helpless conditions, versus freezing as active preparation more likely to be seen in aggressive participants when they are able to fight back.

1. Method

1.1. Participants

30 students at the Radboud University Nijmegen performed the study for course credit or financial compensation. The group consisted of 16 females and 14 males, mean age 24.6 (SD = 7.8). All participants had normal or corrected to normal vision. Inclusion criteria as assessed by self-report were no past or present psychiatric or neurological condition. The study was approved by the local ethics committee and all participants gave written informed consent. The sample size was based on the range found in similar previous studies and on power analyses which indicated sufficient power for the primary within-subject comparisons and exploratory between-subject correlational analyses. There was no stopping-rule that allowed data collection to be stopped before completion.

1.2. Materials and procedure

At the start of the experiment, participants completed a number of questionnaires, of which a Dutch translation of the STAI-T measure of trait anxiety [20,21] and a Dutch version of the STAXI measure of trait aggression [22,23] are reported in the current paper. The State-Trait Anxiety Inventory (STAI; [20]) is used for the assessment of current ('state') and general ('trait') levels of anxiety, of which the trait level was used in the current study. The Dutch aggression questionnaire provides an overall measure of an individual's tendency to lose his or her temper or describe themselves in terms of irritable or hot-headed. This was assessed using the Spielberger Trait-Anger expression inventory, a 10- item subscale of the State-Trait Anger Expression Inventory [22]. Respondents rate the degree to which they react in an angry fashion from 1 (almost never) to 4 (almost always), and responses are summed for a global score. The scale has been shown to have good psychometric properties and there is good support for the measure's construct validity [20].

Following the questionnaires, heart rate and shock electrodes were attached to the participants. The electrocardiogram was measured using a BioPac MP150 system sampling at 200 Hz. Shocks were administered to the second and third fingers of the left hand using a Digitimer Constant Current Stimulator DS7A (www.digitimer.com) and standard Ag/AgCl electrodes. The shock consisted of 1 ms positive current followed immediately by 1 ms negative current. Shock intensity was adjusted to be uncomfortable but not painful per participant.

Participants then removed their shoes and stepped onto a stabilometric balance board to perform the shooting task, after a baseline measurement of the sensor values for the empty board. The board was a custom-made 1 m × 1 m stabilometric platform, of which the pressure at each of its corners was sampled at 200 Hz. The baseline measurement allowed sensor values to be converted to Center of Pressure position, by, per sensor, subtracting the baseline and dividing by the total effect of the subject's weight on the board. Participants were given a joystick to be used as a response device (of which only the button pressed via the index finger was used). Participants held a joystick in their right hand, with the right arm bent and pointing forward and with the left hand supporting the joystick. Responses were given by pressing the trigger fire-button on the stick with their right index finger.

1.3. Shooting task

The shooting task (illustrated in Fig. 1; see Supplementary materials for the visual stimuli of all possible trial sequences) consisted of an introduction, training, and measurement phase. In all phases, the screen showed a view of a parking garage, with an opponent character in the center of the screen, an armed policeman in the background (alternatively on the left or right of the screen per block), and a view of the participant's own "in-task" hands, holding a gun or not. Essentially: There were two opponents, who could be easily visually distinguished. As explained in more detail below, both opponents behaved identically: They both sometimes drew a gun to shoot the participant. However, for one of the opponents, the participant would receive an electric shock when being shot by that opponent. For the other opponents, the participant would not receive the electric shock when being shot, but would see the same visual stimulus of the opponent shooting and was still instructed to try to avoid being shot when possible.

In the *introduction* phase, participants were exposed to the meaning of Safe and Threat opponents and the Armed and Unarmed conditions. First, four trials were presented in which the partici-