Adverse life events, cardiovascular responses, and sports performance under pressure

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Abstract

Research suggests that experiencing a moderate number of adverse life events can benefit future stress responses. This study explored the relationship between adverse life (i.e., non-sport) events and cardiovascular responses to, and performance during, a pressurized sporting task. One hundred participants (64 men, 36 women; M_{age} = 21.94 years, SD_{age} = 4.98) reported the number of adverse life events (e.g., serious accident or injury) they had encountered before completing a pressurized dart-throwing task during which performance was recorded. Before the task, participants' demand and resource evaluations and cardiovascular reactivity were assessed. Adverse life events did not impact demand and resource evaluations. However, participants who reported 4-7 adverse life events displayed cardiovascular responses more reflective of a challenge state (relatively lower total peripheral resistance and/or higher cardiac output) compared to those who reported a lower (<4) or higher (>7) number of events. Furthermore, participants who reported 3-13 adverse life events outperformed those who reported a lower (<3) or higher (>13) number of events. Supplementary analyses suggested that this relationship might be due to a small number of extreme values. However, after outlier analyses, a significant linear relationship remained suggesting that a higher number of adverse life events facilitated performance. The results suggest that experiencing a moderate to high number of adverse life events might have beneficial effects on subsequent cardiovascular responses and performance under pressure. Practitioners should therefore consider prior brushes with adversity when identifying athletes who are likely to excel during stressful competition.

Keywords: Adversity; appraisal; athletic performance; psychophysiology; stress; threat state

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Introduction

It has been speculated that "talent needs trauma" (Collins & MacNamara, 2012, p.907), and that athletes who experience adversities during their personal lives and sporting careers are more likely to perform optimally under pressure. While intuitively appealing, research has only recently examined this notion in an athletic context (Fletcher & Sarkar, 2012; Howells & Fletcher, 2015). Sarkar and colleagues (2015) interviewed 10 Olympic champions who considered encountering sport (e.g., significant sporting failure) and non-sport (e.g., death of a family member) adversities as essential for winning their gold medals. Research on this topic has often employed retrospective qualitative methods that limit causal understanding of the link between adversities and performance (e.g., Fletcher & Sarkar, 2012; Howells & Fletcher, 2015). Thus, the present study offers a quantitative test of the relationship between adverse life (i.e., non-sport) events and pressurized sports performance, using the biopsychosocial model (BPSM) of challenge and threat states as a theoretical framework (Blascovich, 2008).

Akin to cognitive appraisal theory (Lazarus & Folkman, 1984), the BPSM predicts that before a pressurized situation, an individual evaluates the demands of the situation and their resources to cope (Blascovich, 2008). Crucially, these evaluations only occur when an individual is actively engaged in the situation (indicated by increased heart rate [HR] or the number of heart beats per minute; Seery, 2011). When resources are judged to match or exceed demands, an individual evaluates the situation as a challenge. When demands are deemed to outweigh resources, an individual evaluates the situation as a threat (Seery, 2011). Inspired by the theory of physiological toughness (Dienstbier, 1989), the BPSM predicts that these evaluations trigger distinct cardiovascular responses (Blascovich, 2008). A challenge evaluation results in sympathetic-adrenomedullary activation, which releases catecholamines that dilate the blood vessels and increase cardiac activity, resulting in greater oxygenated blood flow to the brain and muscles. A threat evaluation also results in pituitary-adrenocortical activation, which releases cortisol that inhibits dilation of the blood vessels and reduces cardiac activity, resulting in less blood flow. Compared to a threat state, a challenge state is therefore indexed by lower total peripheral resistance (TPR; net constriction versus dilation in the arterial system) and/or higher cardiac output (CO; amount of blood in liters pumped by the heart per minute; Seery, 2011). Importantly, the BPSM conceptualizes challenge and threat as anchors of a single bipolar continuum rather than dichotomous states, leading researchers to examine relative (rather than absolute) differences in challenge and threat (i.e., greater vs. lesser challenge or threat; Seery, 2011).

The BPSM contends that a challenge state is better for performance than a threat state (Blascovich, 2008), and research has supported this assertion (Blascovich et al., 2004; Moore et al., 2012; Turner et al., 2013). To illustrate, Moore and colleagues (2012) found that evaluating a golf competition as more of a challenge was associated with superior performance. In a follow-up study, Moore and colleagues (2013) manipulated experienced golfers into either a challenge or threat state immediately before a pressurized golf-putting task; golfers in the challenge condition outperformed those in the threat condition, holing a higher percentage of putts and leaving the ball closer to the hole on misses. Similar results have been reported for pressurized tasks in educational (Seery et al., 2010), medical (Vine et al., 2013), and aviation (Vine et al., 2015) settings.

Alongside this research, social psychologists have used the BPSM to investigate the relationship between prior exposure to adverse life events and subsequent responses to stress (Seery, Holman et al., 2010; Seery, Leo et al., 2010). Seery and colleagues (2013) assessed participants' histories of negative life events before a computer-based navigation task. Results revealed a curvilinear relationship, with a moderate number of adverse life events (5) related to a cardiovascular response more reflective of a challenge state compared to no (0) or a high (11) number of events. Contrary to the view that experiencing adverse life events increases the risk of future psychological problems (Turner & Lloyd, 1995), this finding suggests that exposure to some negative life events may have a 'silver lining' and benefit individuals during future pressurized situations - helping individuals view such situations as less demanding and/or that they have the ability to cope given their prior adversities. Despite this finding, no research has examined the link between adverse life (i.e., non-sport) events and subsequent cardiovascular responses to, and performance during, a pressurized sporting task. Indeed, experiencing a moderate number of adverse life events might benefit pressurized performance by fostering a challenge state, while encountering a low or high number of adverse events might harm performance by provoking a threat state.

This study aimed to shed light on this issue by examining the relationship between adverse life (i.e., non-sport) events and three outcomes, namely (1) demand and resource evaluations, (2) cardiovascular responses, and (3) task performance. Based on the aforementioned research (Seery et al., 2013), curvilinear relationships were predicted, with a moderate number of adverse life events associated with demand and resource evaluations (i.e., resources exceeding demands) and cardiovascular responses (i.e., lower TPR and/or higher CO) more reflective of a challenge state compared to a low or high number of events. Moreover, it was predicted that experiencing a moderate number of adverse life events would be related to better performance during the pressurized sporting task than a low or high number of events.

Materials and Methods

Participants

One hundred participants (64 men, 36 women; $Range_{age} = 18\text{-}46$, $M_{age} = 21.94$ years, $SD_{age} = 4.98$) were tested individually. Participants reported competing in various team ($n = 57$; e.g., rugby union) and individual ($n = 43$; e.g., equestrian) sports, predominately at a club or university/collegiate level. Importantly, participants declared having no formal dart throwing experience and were thus considered novices. Participants were nonsmokers, free of illness, had no known family history of cardiovascular or respiratory disease, had not performed vigorous exercise or ingested alcohol in the preceding 24 hours, and had not consumed food or caffeine in the preceding hour. The protocol was designed in accordance with the British Psychological Society's guidelines and received institutional ethical approval. After reading an information sheet, participants provided written consent.

Measures

Adverse life events. Cumulative lifetime adversity was assessed using a checklist that asked participants whether they had experienced 37 negative life (i.e., non-sport) events (e.g., serious accident or injury, financial difficulties). Up to six instances of each event was recorded and the number of instances was summed as a measure of adverse life events (as Seery et al., 2013). This checklist, originally derived from the trauma section of the Diagnostic Interview Schedule (Robins, Helzer, Croughnan, Williams, & Spitzer, 1981), was identical to previous measures of adversity (see Seery, Holman et al., 2010). Although this measure does not assess the severity or timing of each adverse event, it has been used in previous research to examine the relationship between negative life events and important outcomes such as psychological wellbeing (see Seery & Quinton, 2016).

Demand resource evaluations. Two self-report items were used to assess evaluations of task demands and personal coping resources respectively (Tomaka et al., 1993): "How demanding do you expect the upcoming dart-throwing task to be?" and "How able are you to cope with the demands of the upcoming dart-throwing task?" Both items were rated on a 6-point Likert scale (1 - *not at all* to 6 - *extremely*). A demand resource evaluation score was calculated by subtracting evaluated demands from resources (range: -5 to +5), with a positive score reflecting a challenge state and a negative score reflecting a threat state. Previous research has used this self-report measure to assess challenge and threat states (e.g., Moore et al., 2013; Vine et al., 2015).

Cardiovascular responses. An ambulatory blood pressure monitoring system (Portapres-2, Finapres Medical Systems, Amsterdam, The Netherlands), which has been shown to be accurate and reliable (see Hirschl et al., 1999), was employed. A finger cuff was attached to the middle finger of their non-dominant hand and was inflated to continuously estimate cardiovascular data. This system estimated HR, TPR, and CO, and has been used in previous research (Zanstra et al., 2010). Cardiovascular reactivity - or the difference between the final minute of baseline and the minute after these instructions - was used to assess whether participants were engaged in the task (a pre-requisite of challenge and threat states; with larger increases in HR reflecting greater engagement), and if they exhibited a cardiovascular response more indicative of challenge or threat (the former characterized by relatively greater decreases in TPR and/or increases in CO; Seery, 2011). Unfortunately, due to signal problems, cardiovascular data from nine participants was not recorded.

Task performance. A dart-throwing task that required participants to throw nine darts to a dartboard (diameter = 44.80 cm; height from floor to bullseye = 1.73 m) from a distance of 2.37 m was used. The dartboard had ten concentric scoring circles, with the innermost circle (bullseye) worth 10 points and the outermost circle worth 1 point (as Coffee et al., 2009). Performance was recorded as a score out of 90, with a higher score reflecting better performance.

Procedure

First, participants completed the measure of adverse life events before being fitted with the Portapres-2. Next, participants sat still and quietly while five minutes of baseline cardiovascular data was recorded. Subsequently, participants received instructions about the dart-throwing task designed to elevate pressure (Baumeister & Showers, 1986). Importantly, these instructions have been successful in increasing pressure in previous research (e.g., Cooke et al., 2010), and informed participants that they would be entered into a competition, with the top five performers awarded prizes and the bottom five performers being interviewed about their poor performance. Participants were also instructed that scores would be published on a leaderboard and videos of their performance may be used in presentations to their peers. Next, one minute of cardiovascular data was recorded while participants reflected on these instructions and the upcoming task. Participants then reported demand and resource evaluations before performing the pressurized dart-throwing task. Following the task, participants had all equipment removed, were debriefed, and thanked for their participation.

Results

Participants reported between 0 and 25 adverse life events (8% reported no events). The mean number of adverse life events was comparable to previous research (i.e., Seery et al., 2013). TPR and CO reactivity were combined into a single challenge/threat index by converting reactivity values into *z*-scores and summing them. TPR was assigned a weight of -1 (i.e., reverse scored) and CO a weight of +1, such that a higher value corresponded with more of a challenge state (as Seery et al., 2009). Data with *z*-scores greater than 2 were removed from further analyses (three values for each of demand resource evaluation score, challenge/threat index, and task performance; as Moore et al., 2013). Following these outlier analyses, all data were normally distributed (i.e., skewness and kurtosis *z*-scores did not exceed 1.96). To assess task engagement, a dependent *t*-test was conducted on the HR reactivity data to establish that, in the sample as a whole, HR increased significantly from baseline (i.e., HR reactivity greater than zero; as Seery et al., 2009). The results confirmed that HR increased by an average of 1.27 beats per minute ($SD = 3.35$), $t(85) = 3.52$, $p = .001$, confirming task engagement and enabling further examination of TPR and CO reactivity (via challenge/threat index).

Descriptive statistics and bivariate correlations were calculated (Table 1). To examine the curvilinear relationships between the number of adverse life events and outcomes (i.e., demand resource evaluation score, challenge/threat index, and task performance), hierarchical regression analyses were conducted. The mean centered number of events was entered at step 1, quadratic term (mean centered events^2) at step 2, and cubic term (mean centered events^3) at step 3. The significance of additional variance explained in the outcomes at each step was assessed. The cubic term was added to allow for additional bends in the modelled curve, accounting for the influence of a small number of extreme adverse life events (as Seery et al., 2013). If a cubic term was significant, the quadratic term at mean adverse life events within the cubic model was examined (as Seery et al., 2013). To explore significant quadratic terms, the linear simple slopes at different levels of adversity were examined (Aiken & West, 1991): 1 *SD* below the mean, at the mean, and 1 *SD* above the mean, representing low, average, and high numbers of adverse life events, respectively. To be consistent with the hypotheses, the slopes of the regression lines would be significant and positive at low adverse life events, not significant at average adverse life events, and significant and negative at high adverse life events. We also determined at which specific number of events the relationships between adverse life events and outcomes became (non) significant. This post hoc probing used values from the variance-covariance matrix of the regression coefficients to calculate the standard errors of the slopes of the regression lines and their 95% confidence intervals (Aiken & West, 1991; Cohen et al., 2003). The slopes of the regression lines were considered significant if their 95% confidence intervals did not contain zero.

The results revealed no significant linear ($R^2 = .01$, $p = .30$), quadratic ($\Delta R^2 = .02$, $p = .14$), or cubic ($\Delta R^2 = .002$, $p = .68$) relationship between adverse life events and demand resource evaluation score. In the challenge/threat index model, beyond non-significant linear ($R^2 = .01$, $p = .30$) and quadratic ($\Delta R^2 = .02$, $p = .16$) components, a significant cubic ($\Delta R^2 = .09$, $p = .004$) relationship was observed between adverse life events and challenge/threat index (Figure 1). Within this cubic model, there was a significant quadratic relationship at mean adverse life events ($b = -0.02$, $p = .001$, $sr^2 = .12$). The slope of this curve was significant and positive at low adverse life events ($slope_{low} = 0.24$, 95% CI 0.10, 0.38), not significant at average adverse life events ($slope_{mean} = 0.05$, 95% CI -0.02, 0.11), and significant and negative at high adverse life events ($slope_{high} = -0.15$; 95% CI -0.27, -0.03).

The slope of the regression line was significant and positive at adverse life events less than 0.11 *SD* below the mean (*slope* = 0.07, 95% CI 0.001, 0.13), and significant and negative at adverse life events more than 0.72 *SD* above the mean (*slope* = -0.09, 95% CI -0.19, -0.0004). These analyses indicated that individuals who reported 4-7 adverse life events displayed a cardiovascular response more indicative of a challenge state than those who reported a lower (<4) or higher (>7) number of events.

Beyond a non-significant linear component (R^2 = .01, p = .46), a significant quadratic (ΔR^2 = .09, p = .003) relationship was observed between adverse life events and performance (Figure 2). The cubic component did not contribute significant additional variance (ΔR^2 = .01, p = .43). The slope of the quadratic relationship was significant and positive at low ($slope_{low}$ = 1.71, 95% CI 0.58, 2.84) and average adverse life events ($slope_{mean}$ = 0.92, 95% CI 0.24, 1.60), but was not significant at high adverse life events ($slope_{high}$ = 0.13; 95% CI -0.33, 0.58). Specifically, the slope of the regression line was significant and positive at adverse life events less than 0.51 *SD* above the mean (*slope* = 0.51, 95% CI 0.002, 1.03), and significant and negative at adverse life events more than 2.15 *SD* above the mean (*slope* = -0.79, 95% CI -1.57, -0.003). These analyses indicated that individuals who reported a 3-13 adverse life events outperformed those who reported a lower (<3) or higher (>13) number of events. Inspection of Figure 2, however, indicated that the quadratic relationship between adverse life events and performance may be due to a small number of data points at extreme values. To further explore this, supplementary analyses were conducted by removing the outliers (>2 *SDs* above the mean) and also (in a separate analysis) winsorizing the outliers to 1% higher than the next highest non-extreme value before repeating the regression analysis. In these supplementary analyses, the quadratic term was not significant (ΔRs^2 < .02, *p*s > .05), but a positive linear relationship was observed within these models (*b*s = 0.77-0.84, *p*s = .05, sr^2s = .04), indicating that a higher number of adverse life events was associated with better performance.

Discussion

It has been suggested that athletes who encounter adversities are more likely to excel under pressure (Sarkar et al., 2015). The present study provides support for this notion in an athletic context, revealing a curvilinear relationship between adverse life (i.e., non-sport) events and pressurized sports performance. Participants who had encountered 3-13 negative life events performed better during the pressurized task than participants who reported experiencing a lower (<3) or higher (>13) number of adverse life events. It should be noted, however, that supplementary analyses suggested that this curvilinear relationship may be due to a small number of outliers, but there was a significant positive, linear relationship between adverse life events and performance. Regardless, these findings suggest that the 'silver lining' associated with encountering a moderate number of negative life events might extend to individuals who have experienced a relatively high number of negative life events (Seery et al., 2013). Although data on the relationship between adverse life events and stressful task performance is scarce, Seery and colleagues (2013) also found that participants exposed to a moderately high number of adverse life events (5-12) performed better in a cold pressor task than participants with low exposure.

Experiencing a moderate number of adverse life events can help individuals respond more adaptively to future stressful scenarios, while encountering a low or (very) high number of events can result in maladaptive responses (Seery et al., 2013). This study is the first to support this notion in a pressurized sporting context, revealing a curvilinear association between adverse life events and cardiovascular response. Importantly, in the sample as a whole, HR increased significantly, confirming task engagement and allowing further examination of TPR and CO reactivity (via challenge/threat index). Compared to participants with a history of low (<4) or high (>7) adverse life events, participants with a history of 4-7 adverse life events responded to the pressurized task with a cardiovascular pattern more reflective of a challenge state (i.e., lower TPR and/or higher CO reactivity). This cardiovascular response is considered more favorable since it results in greater oxygenated blood flow to the brain and muscles, preparing the individual to effectively manage the stressful task (Seery, 2011). Indeed, a cardiovascular response more reflective of a challenge state has been related to better sports performance (Blascovich et al., 2004; Turner et al., 2013). Experiencing a moderate number of adversities might, therefore, benefit future pressurized performance by fostering a challenge state, while encountering a low or (very) high number of adversities might harm future performance by provoking a threat state.

From a BPSM perspective, the divergent cardiovascular responses are likely due to the differences in how participants evaluated the pressurized task. Specifically, relative to a history of low or high adverse life events, experiencing a moderate number of adverse events might have helped participants view the task as less demanding and/or that they possessed greater ability to cope given their prior adversities. Although the cardiovascular data supported this notion, the self-report data did not because there was no relationship between adverse life events and demand resource evaluation score. This unexpected finding could be due to self-report bias. Indeed, participants may have been reluctant to report that they had insufficient coping resources (i.e., social desirability bias). Alternatively, reflecting on the negative life events that they had experienced might have biased participants' subsequent task evaluations, leading them to report it as less demanding (i.e., negative-affect-based recall bias; Watson & Pennebaker, 1989). Such issues have led to the recommendation that challenge and threat states may be best assessed using objective indices (Blascovich, 2008).

The current findings have several implications. First, they counter the belief that adverse life events only have negative effects on future psychological responses to stress (Turner & Lloyd, 1995). Instead, experiencing a moderate number of adverse life events should be viewed as beneficial and might help athletes' in future high-pressure situations. Second, while not encouraging the experience of negative life events, the findings suggest that practitioners should avoid 'sheltering' athletes from stressors and instead, if suitable, appropriately and progressively optimize the sport-related adversities athletes encounter. This might include exposing athletes to higher levels of competition, different sports and playing positions, de-selection from particular events, and competition in foreign countries (Collins & MacNamara, 2012). Indeed, in other professions where individuals are required to act under pressure (e.g., police), exposing individuals to simulated adversities (e.g., reenactment of a robbery) has facilitated better performance in future stressful scenarios (Arnetz et al., 2009; Robertson et al., 2015). Given the present findings, such training might help athletes thrive during pressurized competition, although more research is required before these interventions become common practice. Alongside these implications, it should be noted that the effect sizes were small to moderate. However, given the increasing interest in marginal gains in achievement and health contexts (e.g., Richards, 2015), these effects could translate into the difference between success and failure.

The limitations of this study also offer possible avenues for future research. First, the focus on non-sport (e.g., parental divorce) rather than sport (e.g., repeated non-selection) adversities could be seen as a limitation. Thus, while the findings suggest the ‘silver lining’ associated with experiencing a moderate number of adverse life events is not domain specific, and that athletes’ may benefit from the adversities they have faced outside of sport, future research should examine the role of both types of adversities. Second, this study focused solely on the frequency of adversities; future research should investigate the severity and timing of adversities, and how athletes interpret adverse events (e.g., as an opportunity for growth). Indeed, exposure to fewer but more severe adversities might also be beneficial, while more recent adversities might have a less favorable impact than less recent adversities. Despite the difficulties in assessing the severity of adverse events (e.g., recall bias; Seery & Quinton, 2016), future research should explore these issues as well as the potential for growth following adversity (Tamminen & Neely, 2016), and possible underlying mechanisms and moderators (e.g., social support). Third, participants were limited to university students with no formal dart-throwing experience. Although this enabled data to be collected from a relatively large sample, future research should examine the link between adverse life events and pressurized sports performance across various populations (e.g., experienced athletes), contexts (e.g., real competition), and research designs (e.g., longitudinal). Indeed, given the challenges associated with creating high levels of pressure in laboratory-based environments, future research is encouraged to replicate the current study among elite athletes in top-level competition. Finally, this study investigated the effects of adverse life events on only three outcomes: (1) demand and resource evaluations, (2) cardiovascular responses, and (3) performance under pressure. Future research should examine if experiencing adverse events influences other key psychological outcomes such as burnout, injury risk, and athlete well being.

To conclude, exposure to adverse life (i.e., non-sport) events influenced participants’ cardiovascular responses and performance during a pressurized sporting task. Specifically, experiencing a moderate number of adverse life events helped participants respond to the task more favorably, with a response more indicative of a challenge state. Furthermore, encountering a moderate to high number of adverse life events benefitted performance under pressure. Practitioners should therefore consider prior brushes with adversity when identifying athletes who are likely to excel in high-pressure situations in the future.

Perspective

The present study suggests that the 'silver lining' associated with encountering a moderate number of adverse life events might also extend to experiencing a relatively high number of events. It is therefore important to encourage athletes to view facing adverse events as an opportunity for growth and an experience that might benefit their performance during future stressful situations. While not encouraging the experience of adverse events, practitioners should avoid 'sheltering' athletes and instead, appropriately and progressively optimize the sport-related adversities athletes encounter.

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Tables

Table 1

Means, Standard Deviations, and Correlations for all Variables

	Mean	SD	1	2	3	4
1. Heart rate reactivity	1.27	3.35				
2. Number of adverse life events	4.78	4.23	.05			
3. Demand resource evaluation score	1.35	1.84	-.15	.11		
4. Challenge/threat index	0.44	0.80	.53*	.11	.19	
5. Task performance	53.65	10.47	.00	.08	.33*	.28*

Note. * Denotes correlation significant at .05 level (2-tailed)

Figure Legends

Figure 1. The relationship between the number of adverse life events and challenge/threat index. Within the significant cubic model, there was a significant quadratic relationship at mean adverse life events. The slope of this curve was significant and positive at adverse life events less than 0.11 *SD* below the mean, and significant and negative at adverse life events more than 0.72 *SD* above the mean. These regions of significance are denoted by the vertical dashed lines. Individuals who reported a moderate number of adverse events (4-7) displayed a cardiovascular response more indicative of a challenge state than those who reported a low (<4) or high (>7) number of events.

Figure 2. The relationship between the number of adverse life events and task performance. The slope of the quadratic relationship was significant and positive at adverse life events less than 0.51 *SD* above the mean, and significant and negative at adverse life events more than 2.15 *SD* above the mean. Individuals who reported a moderately high number of adverse life events (3-13) outperformed those who reported a low (<3) or very high (>13) number of events.

Figure 1.

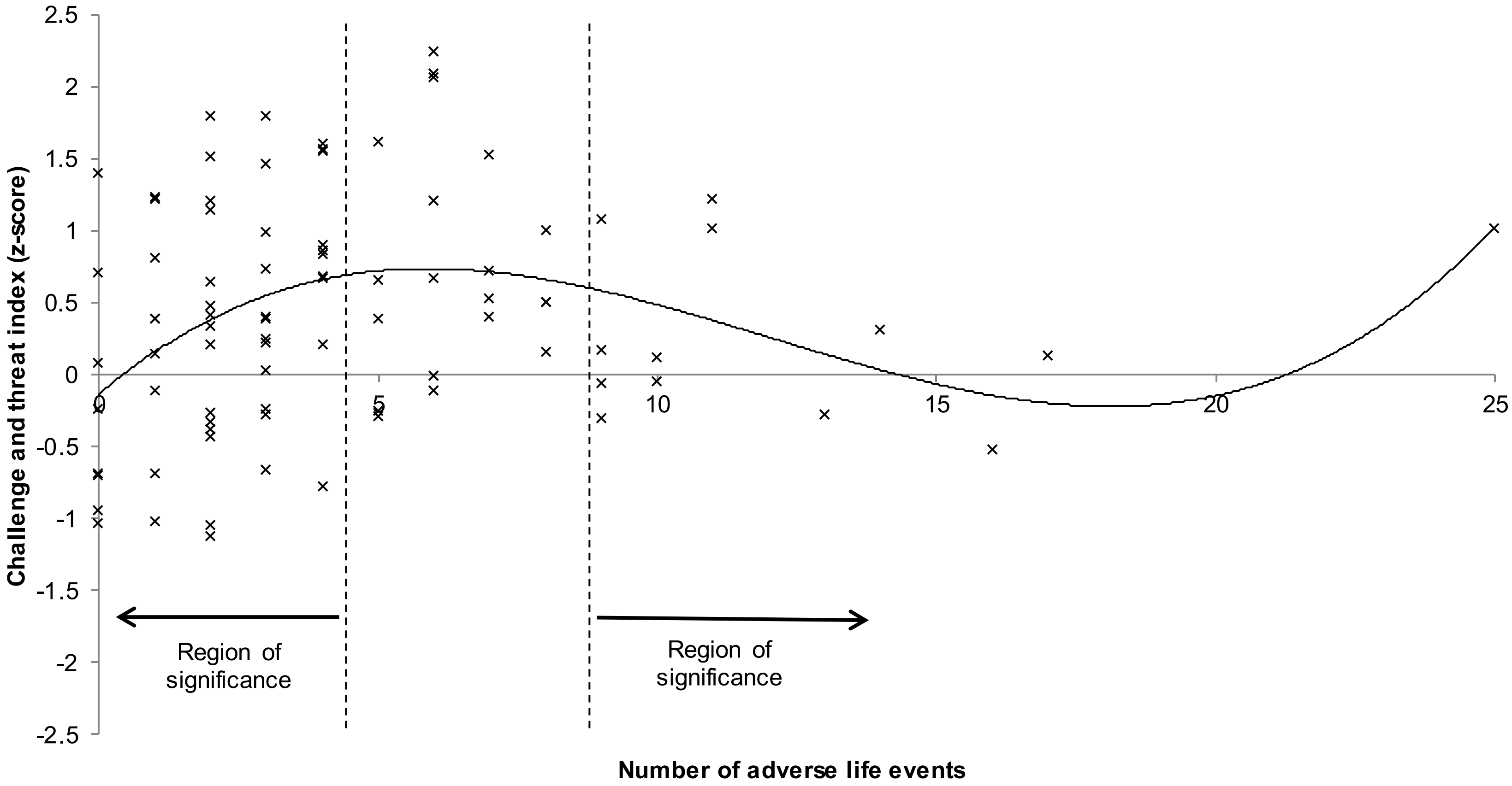
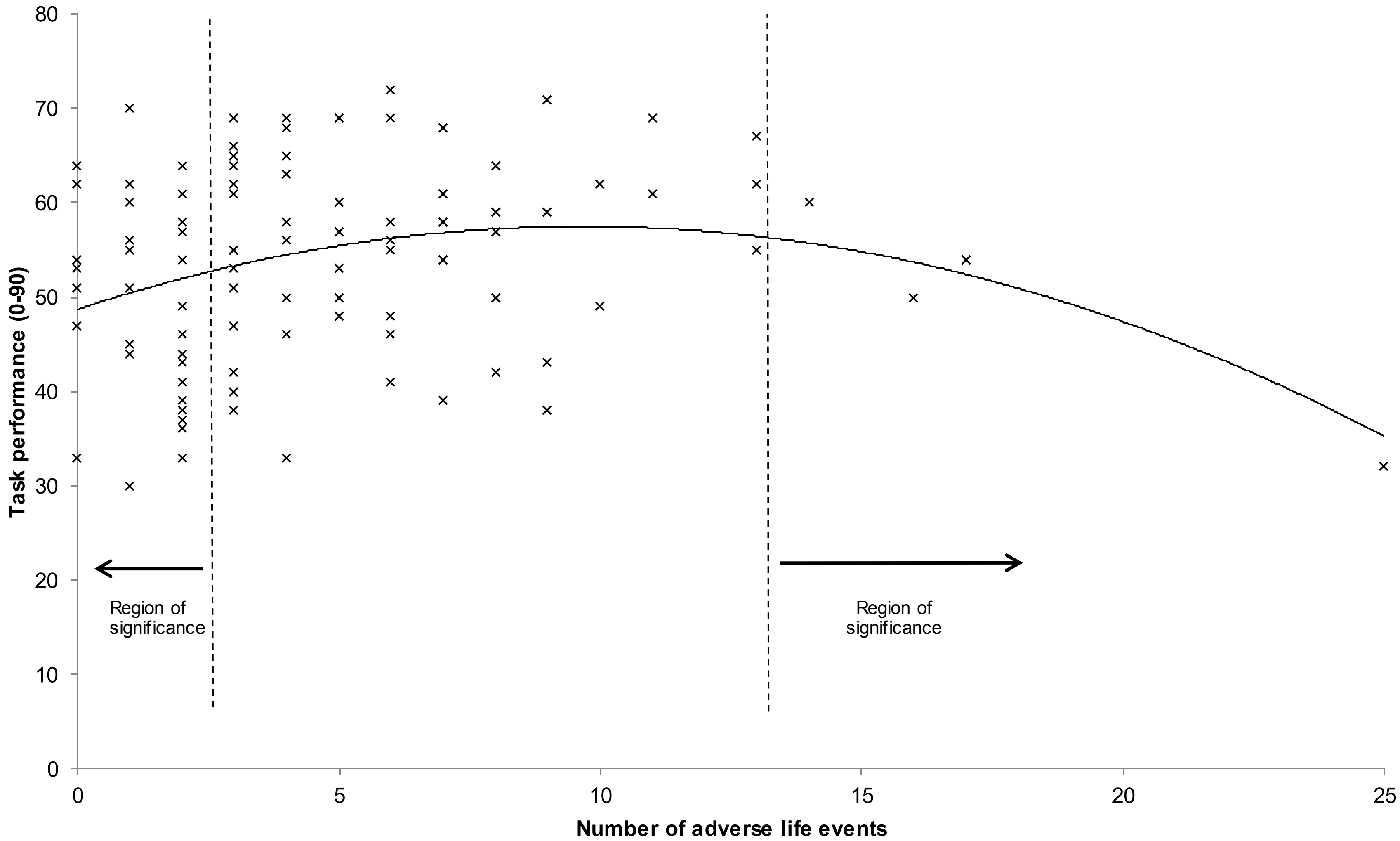

2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
0
5
10
15
20
25
Challenge and threat index (z-score)
Number of adverse life events
Region of significance
Region of significance

Figure 2.


Task performance (0-90)
80
70
60
50
40
30
20
10
0
Region of significance
Region of significance
0
5
10
15
20
25
Number of adverse life events