MASTERARBEIT | MASTER'S THESIS

Titel | Title

The Impact of Stress Resilience on Stress Response following a Loss of Control inducing Game

verfasst von | submitted by

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angestrebter akademischer Grad | in partial fulfilment of the requirements for the degree of

Master of Science (MSc)

Wien | Vienna, 2024

Studienkennzahl lt. Studienblatt | Degree programme code as it appears on the student record sheet:	UA 066 840
Studienrichtung lt. Studienblatt | Degree programme as it appears on the student record sheet:	Masterstudium Psychologie
Betreut von | Supervisor:	Univ.-Prof. Mag. Dr. Claus Lamm

Abstract

Perceived control is a crucial factor in overall wellbeing. It can act as a protective factor against stress, improve life expectancy in the elderly, and positively impact mental health. While resilience is generally considered a protective factor against stress, its effects on the response to acute stress are mixed, as noted by several studies. Therefore, investigating the impact of a loss of control on stress levels can enhance our understanding of resilience. In this study, 24 participants played a browser game over 16 rounds and experienced increasing levels of loss of control. The participants' stress levels were measured using subjective stress questions and heart rate during the game. The German version of the Brief Resilience Scale (BRS) was used to determine the resilience of the participants. The study found that subjective stress levels were higher when participants experienced a greater loss of control. In contrast, heart rate and heart rate variability did not show this effect. Additionally, BRS scores did not influence heart rate or heart rate variability but did influence perceived stress. These results suggest that participants felt subjective stress but did not exhibit a physiological response to stress. BRS scores also did not influence participants attribution of the outcome of the game.

Contents

Introduction

In our daily life, the concept of control holds a central place. Whether it is as small as deciding what to eat for lunch or as big as how to live ones live. Being able to control our actions is a core aspect of feeling a certain freedom of choice. A lack of it is often used as a punishment in society. The ability to influence our environment, make choices, and navigate life's challenges can mitigate our well-being.

Stress

Stress and its effect on the human body is something we experience daily in various situations and, to some extent learnt to cope with. The strategies how we cope might vary from person to person. The term "stress" can have different meanings, but in a psychological context, commonly is used to describe a negative affect which can have different emotions alongside it, such as frustration, anxiety, or anger (McEwen & Karatsoreos, 2011). In a psychological context, there are different definitions of stress and its effects. One of them suggests that stress stems from situations that are unpredictable und uncontrollable, and therefore create an uncomfortable state of stress in a person (Seligman, 1972; Koolhaas et al., 2011).

Generally, differences between acute stress and chronic stress are made in stress research. The former described an acute stress response to a specific situation, the latter describes the cumulative effect of acute stress over a longer period of time (Epel et al., 2018). An acute stress response leads to changes in the autonomic nervous system and hormonal balance within the body. These changes can be measured and are used as biomarkers of stress in research. Cortisol levels, heart rate and heart rate variability are such commonly used biomarkers.

The consequences of stress on health and well-being are various. Brain imaging of healthy adults who have experienced stress in their early life shows morphological changes compared to adults who did not face early childhood stress (De Bellis, 2005). A study by Spinelly et al. (2009) carried out on rhesus monkeys, has compared juvenile brains before and after early life stress and found significant differences in various brain regions compared to primates which have not faced stressors. Furthermore, stress has been identified as a risk factor for various diseases like infectious or cardiovascular diseases (Cohen et al., 2007).

However, not all stress is necessarily negative for our wellbeing. According to a study conducted with veterans (Karlsen et al., 2006), coping with stress in a problem-focused manner can mediate its effects and even have a positive impact on subjective wellbeing. This shows the importance of understanding in which way people cope with stress and especially why some people can grow as a person when facing stress. The concept of stress resilience is one aspect to take into consideration and is discussed in further detail in the below.

Stress Resilience

Not everyone is experiencing stress and its negative outcome in the same way, as individuals react and cope differently with it and therefore have different stress resilience (Mancini & Bonnano, 2009). Generally, stress resilience is the ability to adapt and overcome stressful situations or events while also maintaining functionality in a psychological and physical sense. (Wu et al. 2013). In its most basic definition, stress resilience is often referred to as the ability to bounce back from stress (Smith et al. 2008). The underlying mechanisms of resilience are believed to be sourced from a wide variety of factors including genetic, psychological, developmental, and neurochemical (Rutten et al., 2013; Wu et al. 2013). Early childhood experiences can have lasting effects on adult behaviour in stressful situations and their coping strategies.

Some of the defined characteristics of resilience from Wu et al. (2013) include optimism, active coping, self-confidence, and a strong social network among others, showing the complexity and multidimensionality of resilience.

In terms of how resilience is influencing our well-being, a meta-analysis by Hu & Wang (2015) showed that as a trait, resilience is negatively correlated with depression and anxiety. In other words, people with lower resilience showed higher levels of the aforementioned negative mental health outcomes. Resilience was also shown to be a protective factor against negative life events, thus playing an important role in dealing with stress factors in our lives.

Findings regarding the relationship of resilience and stress response in acute stressful situations are rather mixed. Some studies have found no relation between resilience and cortisol levels during a stress test (García-León et al., 2019, Zapater-Fajarí et al., 2021), whilst others have found that participants who scored higher in stress resilience had a lower cortisol activity in a stress test than participants with lower levels of stress resilience (Mikolajczak et al., 2008, Ruiz-Robledillo et al., 2016). This strongly suggests further research is needed regarding the protective qualities of resilience against acute stress are needed.

It should be noted that there are multiple definitions of resilience, and there is a lack of longitudinal studies making it difficult to identify characteristics of resilience that have a lasting effect on mental health after a stressful situation (Kalisch et al., 2017).

Autonomic Nervous System as a Measure of Stress

To understand heart rate (HR) and heart rate variability (HRV) as a way to measure stress response, it is important to comprehend the nature of the autonomic nervous system (ANS). The ANS can be seen as a three-component system including the parasympathetic (PNS), the sympathetic (SNS) and enteric nervous system (Iversen et al., 2000; ten Donkelaar, 2020), with the former two being discussed in greater detail below. The PNS generally keeps the homeostatic heart frequency and has inhibitory effects on the heart rate, whereas the SNS functions to increase the heart rate, which can also be seen in response to a stressor (Ernst, 2013, Ernst 2017). HRV can depict changes in the ANS, more specifically between the PNS and SNS (Kim et al., 2018), as it measures changes in heart rate from beat to beat, and therefore the time between consecutive heartbeats. A higher HRV describes a healthier response of the body to stress on a cardiovascular level. These HRV changes can be seen as a stress response in participants in different studies, as shown in a meta-analysis by Kim et al. (2018). A meta-analysis by Castaldo et al. (2015) showed most of examined studies came to the conclusion that HRV does indeed show a shift to sympathetic activation of the ANS during acute stress tasks. Studies showed the use of electrocardiogram (ECG) as a valid measurement for stress induced HR and HRV changes (Berkaya et al., 2018; Karthikeyan et al., 2013)

Feeling of Control

Perceived control, the subjective feeling of control a person has in a situation, has two elements: (1) Perception that a situation can be controlled and (2) taking the correct action is an option (Steptoe & Poole, 2016). In some cases, individuals may experience a sense of control, but struggle to take action due to a lack of necessary skills. This can hinder their ability to act in the given situation and create a sense of loss of control.

Control can have a significant effect on the general wellbeing of people. It was shown that people who experience anxiety at the dentist, feel less stressed if they are told that a hand signal stops all procedures. Even if the hand signal is never used, the levels of stress and even pain are reduced during the procedure (Steptoe & Poole, 2016). Langer & Rodin (1976) designed a study to show the effects of control on elderly nursing home residents. To facilitate a higher feeling of control, one group in the nursing home were given a speech by the medical administrator which emphasised their responsibility for themselves, whereas the control group were informed that the staff had responsibility for its residents. Moreover, residents in both groups were given a plant. Residents with high responsibility were taking care of this plant by themselves, whereas in the control group the plant was watered by the staff. It was found that residents who were given a greater sense of control and responsibility, scored higher in health and activity patterns and had a lower mortality rate than the group with low control. These effects were still noticeable 18 months after the intervention.

Similarly Steptoe & Willemsen (2004) found that individuals who had a low feeling of control in their job (e.g. how frequently they can take breaks on their own terms) had a higher systolic and diastolic blood pressure compared to the high job control group. This correlation was not observed between blood pressure and job strain. Additionally, they also had a higher subjective feeling of stress throughout the workday, than peers with higher perceived control.

A high *locus of control* – the feeling of control in life choices – has also been shown to be a protective factor from acute myocardial infarction in a study with cases from 52 countries (Rosengren et al., 2004). Corresponding with these discoveries, individuals with asthma who reported a heightened perceived control over their condition exhibited improvements not solely in their physical well-being but also in their mental health. This manifested as a reduction in depressive symptoms and an enhanced perception of overall quality of life (Calfee et al., 2006).

A study about the effect of control on the unlearning of fear response by Hartley et al. (2014) showed, that participants who faced inescapable stress (IS) then had a harder time to unlearn a fear response. Participants in this condition first got mild unescapable electric shocks and then were conditioned to fear a certain shape, because it also meant that they got electric shocks. Fear expression was higher than a control group that did face escapable stress (ES) previously, even when no electric shocks were administered for the feared shape. ES participants' performance was modulated by the subjective belief of control a participant thought they had in the task, but also how much they thought salient life events were controllable in general. Participants that scored higher in control were more successful in unlearning the fear response.

A feeling of control seems to have an important role in our health, as it can not only affect stress levels, life expectancy, and learning behaviour but also act as a protective factor against psychological disorders.

Learned Helplessness

The concept *of Learned Helplessness* was introduced by Seligman (1967). He tested the effect of control and loss of it on dogs. In a shuttle box the dogs could escape electric shocks if they learned to jump over a barrier to the side of the box that is devoid of electric shock. Around 94% of dogs learned this behaviour. If the dogs were previously given uncontrollable electric shocks, the majority of them were unable to learn the avoidance behaviour and instead passively accepted the shocks. Even if these dogs crossed over the barrier occasionally, they did not consistently show this pain avoidance. Seligman called this behaviour *Learned Helplessness*, a concept that postulates when an individual encounters uncontrollable trauma, they will also feel helpless in traumatic situations in the future, even if those situations are controllable. Seligman saw *Learned Helplessness* as a key element of depression. Seligman (1972) saw three effects that take place after uncontrollable trauma: (1) passivity when faced with traumatic events; (2) difficulties in learning avoidance behaviour when facing traumatic events, even if it is possible; (3) higher levels of stress when facing uncontrollable traumatic events.

A study by Diener & Dweck (1979) categorised children as either helpless or mastery-oriented in order to investigate the reactions of failure in both groups. Children were put in the helpless group if they scored low in the Intellectual

Responsibility Scale (IAR), which determines the attribution of a situation to either external or internal responsibility, and as a subscale also the attribution of failure due to a lack of effort. In this scale the children were given situations with either positive or negative outcome regarding achievements. The child then must attribute the outcome either to external or internal responsibility. After this the children faced eight solvable problems and four unsolvable problems to determine their reaction to failure. In order to do that the children were questioned about their performance after the tasks. The results showed that firstly, success was not a buffer for negative effects of failure for children in the helpless group. Secondly these children also underestimate the amount of success they had in the task compared to the control group. They also overestimated the success and performance of other children, compared to the control group. Interestingly, success was also not attributed to their own abilities and was re-evaluated after failure in regard to the predictability of future success.

The cause of *Learned Helplessness* was later specified, as the feeling of losing in one specific situation is not automatically transferred to different situations. Alloy et al. (1984) proposed that the causal attributions (global vs. specific) a person makes, and similarity of situations have a key influence on whether the person will feel helpless again. The study showed that having a global attribution style for negative outcomes was an indicator for transferring *Learned Helplessness* to similar and dissimilar situations.

Attribution Style

The role of attribution was first discussed by Heider (1958) and is still a well used concept in psychology. Heider introduced *dispositional attribution* and *situational attribution*. The former is used when people explain a certain causality due to individual's internal factors whereas situational attribution searches explanation outside of the person (e.g. circumstances).

Later on, the terms of internal and external attribution were introduced by Abramson et al. (1978) and were connected to causal failure and success attribution. A person could therefore attribute the outcome of an event either internally, as in the outcome's cause was mostly due to themselves, or externally, as in the outcome's cause was mostly due to circumstances outside of their own responsibility. The authors also suggested that if a person consistently attributes failure internally and success externally, it could be a sign of depression, especially if this internal attribution is also stable and global in the face of failure. This attribution style was later called depressive attribution style by Seligman et al. (1979). In this case, attribution for success is also attributed to external, specific, and unstable factors in addition.

The correlation between depression and this depressive attribution style as described by Seligman et al. (1979) was later shown in various studies (Sweeney et al., 1986, Tianqiang et al., 2015). However, it is not clear which one needs to be present first in order to cause the other.

Hypothesis

From these previous findings the following hypotheses were investigated in this study:

$H1_a$: Participants that score high in resilience are overall less stressed over a game that induces loss of control, compared to participants who score low in resilience.

$H1_b$: Participants that score high in resilience have a higher heart rate variability and a lower heart rate over a game that induces loss of control, compared to participants who score low in resilience.

H2: Participants that score high in resilience feel overall less internal attribution when losing in a game that induces loss of control.

Methods

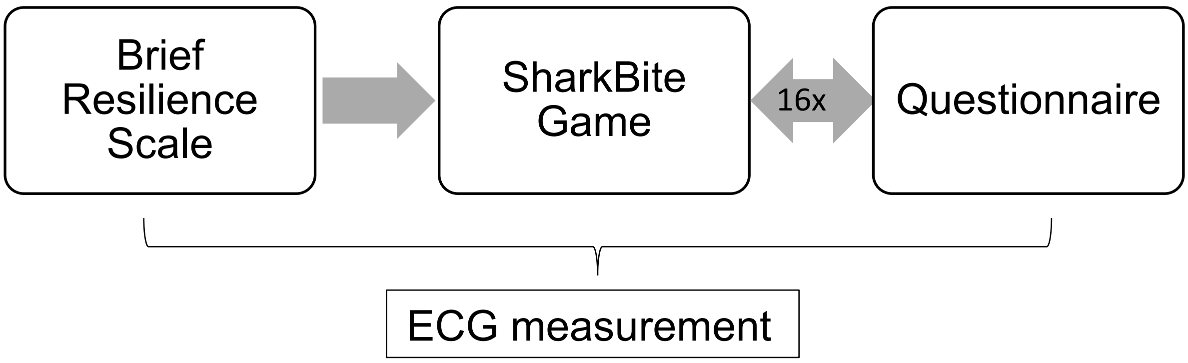
Overview

Participants were able to register by themselves via an online study recruiting platform and were given 10€ for participating in the study but could increase their pay further by gaining treasures during the game. The duration of the experiment was approximately one hour per person and took place at the University of Vienna. Participants were tested individually due to the use of an ECG device.

Participants were provided with an initial overview of the study design and their required tasks. They were then asked to review and sign a consent form. After answering any open questions, participants were instructed to apply the ECG device electrodes themselves. Written and verbal instructions were provided to them in order to guide them through the application. Participants were given privacy during the application of electrodes. Every step afterwards was done on a computer. Participants started by completing a questionnaire which included the Brief Resilience Scale and general demographic questions. After completing the questionnaire, participants played the tutorial of the SharkBite game, after successful completion of which the main game of 16 rounds was started. Following each round, participants provided feedback on various aspects of the game using a sliding scale. More information on these questions can be found in the 'SharkBite Game' section. A debriefing session followed, and participants filled in a payment form to receive their compensation.

Figure 1

Experiment Protocol



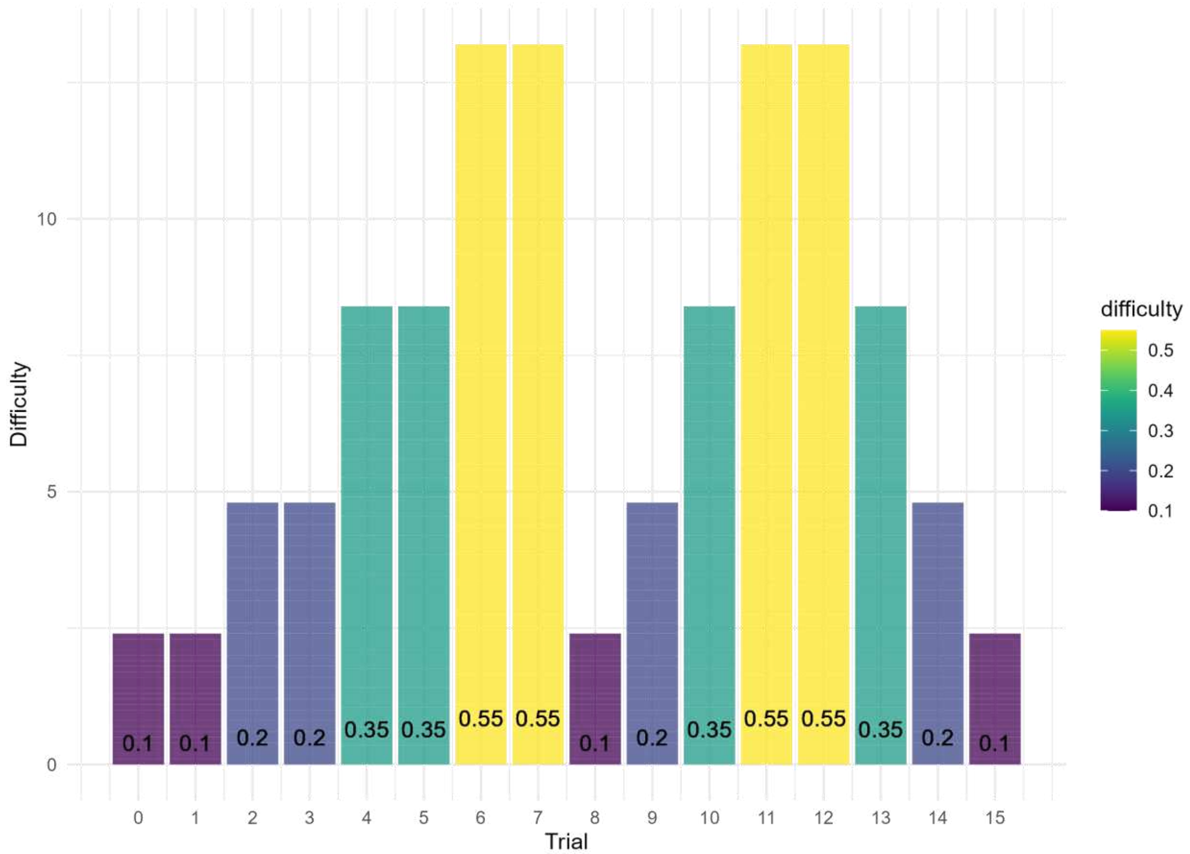
Note. This shows the study procedure. Starting with the Brief Resilience Scale, then the SharkBite Game over 16 rounds. After each round a question regarding attribution and stress is asked. The ECG measures are taken during the whole time period.

SharkBite Game

The objective of the game is to evade a shark while playing as a windsurfer. The surfer can either go to an island with a treasure that is far away, or an island without treasure that is closer to the starting point of the surfer. Movement is advised only when the shark is submerged, as it will otherwise move quickly in the direction of the player. If the shark is underwater, it moves towards the player slowly and the player is now able to make a move in the most efficient way. The shark will then reappear, and the player must wait again for the shark to go underwater. Sometimes winds will push the surfer in a random direction when they make their movement. The player is told that adjusting the sail will give them more control over the random winds. This is indeed not correct, as the sails have no influence on the winds, as their strength and appearance are predetermined by the game, and identical for all players. The probability of being pushed by wind on a move per round is visualised in *Figure 2*.

Figure ***2***

Probability of Wind per Round



Before participants started the game, the study coordinator explained to them that they needed to get at least 8 treasures by the end of the game, in order to ensure the data evaluation was sufficient. This was solely done to put more pressure on participants as the number of treasures was not relevant to the data analysis. Additionally, they were told, that every treasure they kept at the end of the game would give them a bonus of 50 cents, with the aim to future motivate participants. Participants all played a tutorial of the game first to introduce the rules and controls. It also ensured that participants understood the mechanics of the game, as they were otherwise unable to proceed.

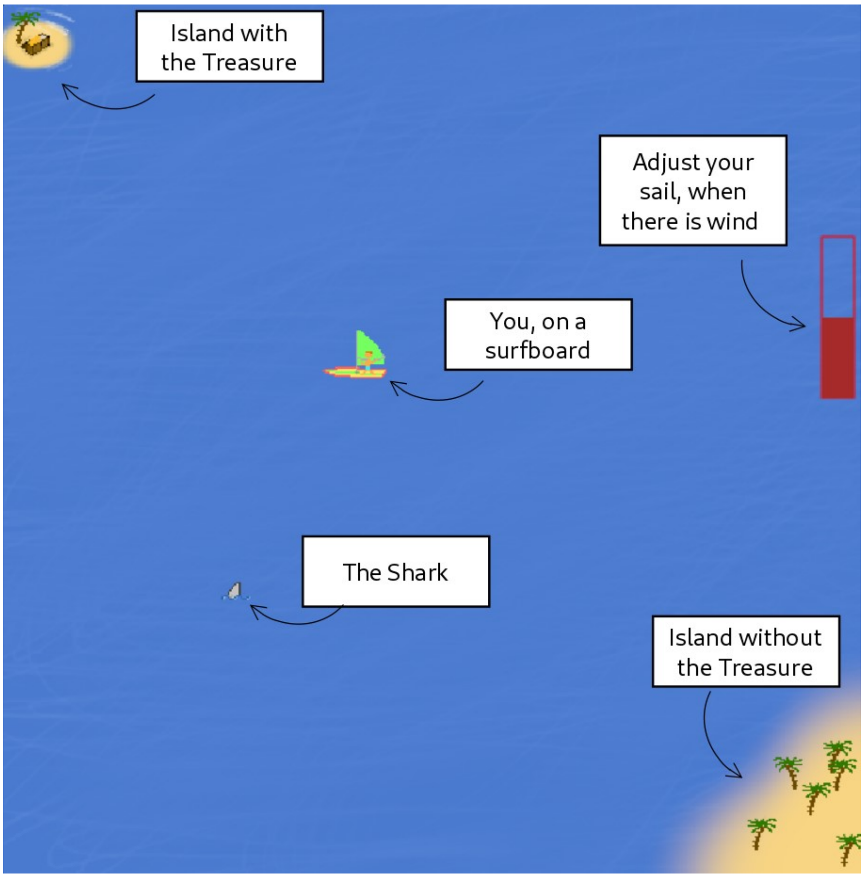
In the game, participants now tried not to get eaten by the shark, as that lead to losing a treasure. Movement was done by using the arrow keys on a standard keyboard and the sail was adjusted with the keys “T” and “G”.

To summarise, reaching the faraway treasure island added one treasure to the participant’s score, getting caught by the shark reduced the treasure score by one. Reaching the close island was neither added nor reduced the treasure score. It is never possible to have fewer than zero treasures at any point in the game.

Sixteen rounds of the game are played, and one round ends when either an island is reached or the player is caught by the shark.

Figure 3

Screenshot of the SharkBiteGame



Note. The screenshot shows the surfer and the shark underwater in the middle. Additionally, there is an island with treasure in the top left corner and an island without treasure in the bottom right corner. The bar on the right indicates the sail adjustment.

Self-assessment Questionnaire

After each round the participants are asked to answer five questions about their previous round experience regarding enjoyment, stress level, level of control in the round, whether the outcome was luck or performance, and if they thought the sail had an effect. For this part of the study, only the question regarding the outcome ("Was the outcome of the game more dependent on chance or your performance?" with a slider ranging between "Chance (Luck)" to "Performance") and stress level ("How stressed do you feel right now?" with a slider ranging between "not at all" to "very much") were looked at.

Brief Resilience Scale

The Brief Resilience Scale (BRS) is a six-item questionnaire, which tests the ability to bounce back from stress (Smith et al. 2008). Each question is answered on a 5-point Likert scale that ranges from 1 “Strongly disagree” to 5 “Strongly agree”. The questionnaire showed a strong correlation with optimistic characteristics, a sense of purpose in life, positive reframing coping strategies, active coping, and acceptance of the situation. Conversely, amongst other things it exhibited a negative correlation with symptoms of depression and anxiety, denial of the situation, and general pessimism.

Internal consistency of the items was between .80-.92 (Cronbach’s alpha). The ICC was indicated as .69, which would be defined as moderate by guidelines defined by Koo & Li (2016); however, due to the lack of reported information on the exact testing procedure, it should be noted that the interpretation of the ICC should be done with caution.

For this study the German version (Chmitorz et al., 2018) of the BRS was used. It was validated on two large population-based samples (n_1 = 1481; n_2 = 1128). Similar to the study of Smith et al. (2008) discriminant validity was determined by its correlation with coping style, mental health, general wellbeing, social support and optimism. It was expected that these aspects positively correlate with the BRS. The study confirmed these expectations.

Reliability of the German version was good with α = .85 (Cronbach’s α) in both samples. For convergent validity Average Variance Extracted (AVE) was calculated and deemed acceptable with a score of .55. indicating that on average 55% of the variance of each indicator is explained by the latent variable.

Heart Rate and Heart Rate Variability

Heart Rate was measured during the questionnaire and the SharkBite Game with a sample rate of 1000Hz with a Bittium Faros 180 ECG device. This device uses three electrodes for monitoring heartbeat. The time during the questionnaire was used as the baseline. Heartbeat annotations were calculated in Matlab with the *HRVTool* by Marcus Vollmer (2015, 2019) and then later in Rstudio (2024). The statistical analysis used the average heart rate per round for each participant, and the standard deviation of normal-to-normal intervals (SDNN) as a measurement for heart rate variability per round for each participant.

Participants

Participants were recruited via the paid study option on Vienna CogSciHub, an online platform for study participation.

In the end data from 24 participants (*n* = 17 female, *n* = 6 male, *n* = 1 non-binary) was analysed. Participants age ranged between 19 years and 40 years with an average age of 26 years. 16 participants (66%) were 24 years or younger. 4 ECG datasets were corrupted and could therefore not be used, resulting in *n* = 20 for ECG analyses.

It has to be noted that data collection for the overall study is still ongoing, and this study describes the sample size at the point the data was analysed. Participants were able to withdraw from the study at any given time and the study underwent approval by the ethics committee of the University of Vienna.

Statistical Analysis

The analysis was done in RStudio (RStudio Team, 2024) with the lm4 library used for calculating mixed models (Bates et al., 2015).

First, BRS scores were calculated following the instruction from Smith et al. (2023), by first reverse coding the items that were worded negatively (Item 2, 4, and 6) and then calculating the means for each participant. This was then used to calculate z-scores for standardization.

Secondly, a manipulation check was done to ensure participants were stressed when they encountered more loss of control and when they were eaten by the shark compared to having more control and not being eaten. Linear mixed models were used to analyse this data. The probability of encountering wind is defined as the amount of loss of control participants encountered and therefore referred to as 'difficulty' in the following. With subjective stress as the dependent variable, predictor variables were difficulty and being eaten by the shark.

In order to investigate the effect of the two predictor variables, difficulty and resilience (BRS scores) on the subjective stress levels and heart rate over repeated measurements, once again linear mixed models were used. Three models were fitted: the first with the difficulty as a fixed effect, the second added BRS scores as a fixed and random effect and the third also added an interaction term between the two predictor variables. It was also investigated if getting eaten by the shark had an effect on these results when added as an interacting variable. This all was done to find the best model fit. In order to answer whether resilience and difficulty have an influence on heart rate and heart rate variability, the same was done with heart rate and heart rate variability as dependent variables.

Finally, the same was done with attribution score used as the dependent variable in order to answer whether attribution changes with different resilience scores and getting eaten added as a fixed and random effect. In all models, random intercepts and slopes for difficulty and being eaten were incorporated to account for variability across different participants.

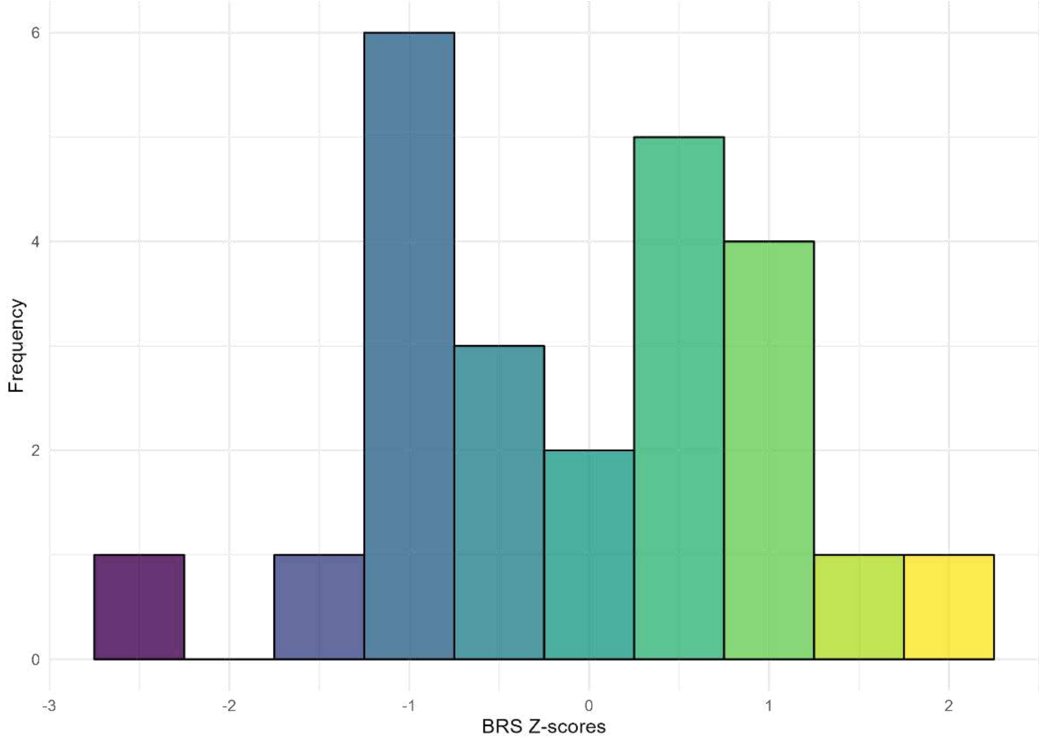
Results

BRS Scores

Mean scores ranged from 1.66 (z = -2.27) to 4.5 (z = 1.85) with a mean of 3.23 (z = 0) and a standard deviation of 0.68 (z = 1). Comparing the results to the validation study of the German version of the BRS (Chmitorz et al., 2018), participant’s scores in both Sample 1 (M = 3.58, SD = 0.76) and Sample 2 (M = 3.37, SD = 0.95) were higher in the validation study than in this one. Results in the original validation of the English version by Smith et al. (2008) for 4 samples (Sample 1: M = 3.53, SD = 0.68; Sample 2: M = 3.57, SD = 0.76; Sample 3: M = 3.98, SD = 0.68; Sample 4: M = 3.61, SD = 0.85) were all slightly higher as well. Distribution of scores can be seen in *Figure 3*

Figure 4

Distribution of BRS z-sores



Manipulation Check

Subjective stress levels were compared round per round with the difficulty (Loss of Control) encountered per round using generalized linear mixed models. The results indicate a significant effect of difficulty on the subjective stress (β = 0.16, *SE* = 0.73, *t* = 2.22, *p* = .03) suggesting that for every 1% increase in difficulty, subjective stress levels increased by an estimated 0.16 points, with a 95% confidence interval (CI) ranging from 0.02 to 0.30. Additionally, there were significant effects of being eaten by the shark (β = 0.46, *SE* = 0.09, *t* = 5.1, *p* < .001) with a 95% confidence interval between 0.28 and 0.64. These results indicated that increased difficulty (loss of control) and being eaten by the shark are associated with self-reported stress, suggesting a successful stress induction.

Figure 5

Effects of Difficulty on Subjective Stress

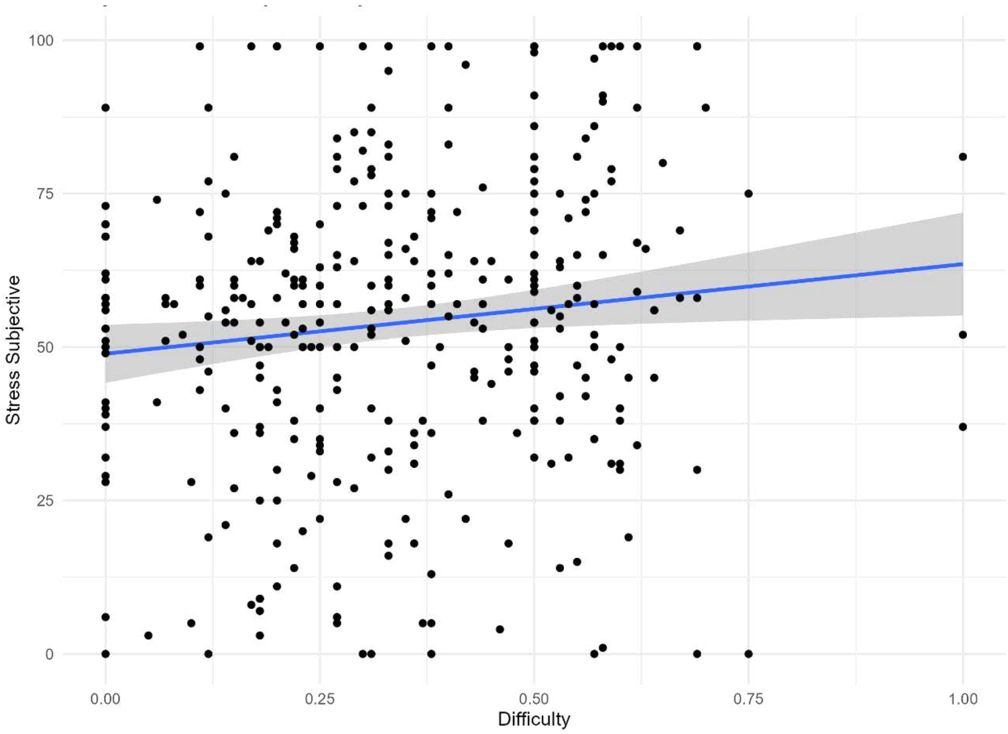


Table 1. Effects on Subjective Stress

Predictor	*Estimates (β)*	*SE*	*t-value*	*p*
difficulty	0.16	0.73	2.22	.03*
eaten	0.46	0.09	5.10	< .001***
BRS score	-0.27	0.12	-2.30	.03*

Note. Significance codes: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

The effects of difficulty on participant's heart rate were not significant (β = -0.19, *SE* = 0.37, *t* = -0.52, *p* = .60) with a CI ranging from -0.97 to 0.51. Secondly, there was also no significant effect on participants' heart rate when being eaten by the shark (β = 0.40, *SE* = 0.47, *t* = - 0.85, *p* = .40) with the CI ranging from -0.52 to 1.29.

Difficulty (β = -0.11, *SE* = 1.31, *t* = 0.08, *p* = .93) with a CI ranging from -2.50

to 2.70 and getting eaten by the shark (β = -2.30, *SE* = 1.74, *t* = -1.32, *p* = .20) with a CI ranging from -5.79 to 1.08 also did not influence HRV. These results indicate that on a biological level, participants showed no sign of a stress response.

The Effect of Resilience on Subjective Stress

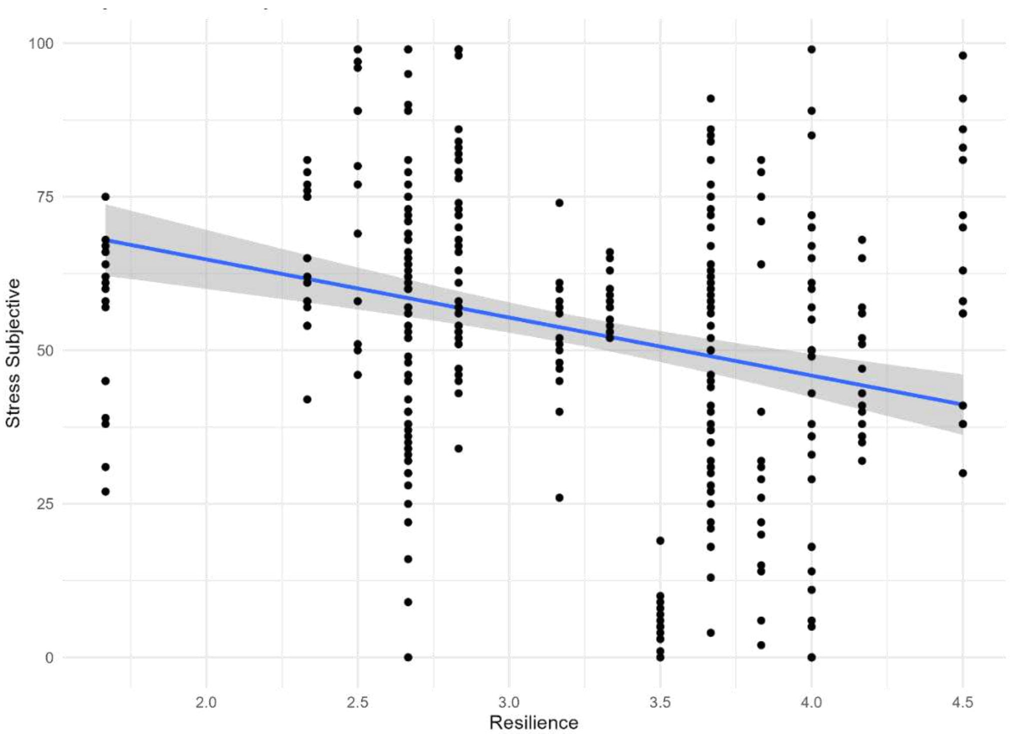
BRS scores (resilience) showed a significant effect on subjective stress levels of participants (β = -0.27, *SE* = 0.12, *t* = - 2.30, *p* = .03) with a CI ranging from -0.51 to -0.04. These findings show a negative correlation between BRS scores and subjective stress, suggesting that participants with more resilience reported less stress.

Adding being eaten to the model, showed that difficulty (β = 0.16, *SE* = 0.73, *t* = 2.22, *p* = .03) with an CI ranging from 0.02 to 0.30 and being eaten (β = 0.45, *SE* = 0.08, *t* = 5.08, *p* < .001) with an CI ranging from 0.28 to 0.62 have a significant effect on the subjective stress of participants, whereas BRS scores (β = -0.22, *SE* = 0.12, *t* = -1.80, *p* = .08) with an CI ranging from -0.48 to 0.04 have not.

The interaction between BRS scores and difficulty (β = -0.25, *SE* = 0.07, *t* = -0.34, *p* = .73) with an CI ranging from -0.16 to 0.11, and BRS scores and getting eaten by the shark (β = -0.01, *SE* = 0.09, *t* = -0.01, *p* = .98) with an CI ranging from -0.18 to 0.11, were both not significant in their effects on subjective stress. This suggests that the effect of BRS scores on subjective stress is not changing with regard to difficulty and in the event of being eaten.

Figure 6

Effect of Resilience on Subjective Stress



The Effect of Resilience on Heart Rate and Heart Rate Variability

As seen in *Table 2,* for the effects of BRS scores on participant's heart rate (β = 0.63, *SE* = 2.17, *t* = - 0.29, *p* = .77) with a CI from -3.9 to 5.13 and in *Table 3* for participants heart rate variability (β = -0.69, *SE* = 2.55, *t* = -0.24, *p* = .81) with a CI ranging from -5.63 to 4.32, both showed to be non-significant. This indicates that participant's resilience score had no influence on the heart rate or heart rate variability during the game.

Adding the event of getting eaten by the shark to the model as a variable shows also a non-significant effect of BRS scores on heart rate (β = 0.33, *SE* = 2.29, *t* = 0.15, *p* = .89) with a CI from -4.14 to 4.81 and heart rate variability (β = -2.56, *SE* = 2.23, *t* = -1.14, *p* = .26) with a CI ranging between -6.93 to 1.82. The interaction between BRS scores and difficulty on average HR (β = -0.09, *SE* = 0.34, *t* = -0.26, *p* = .79) with a CI ranging between -0.79 to 0.57 and HRV (β = -0.21, *SE* = 1.19, *t* = -0.18, *p* = .85) with a CI ranging between -2.60 to 2.10, are both non-significant as well, indicating that BRS scores did not influence the effect of difficulty on the biological stress response. The same was found for the interaction between BRS scores and getting eaten on HR (β = 0.60, *SE* = 0.43, *t* = 1.39, *p* = .17) with a CI ranging between -0.24 to 1.44. A significant interaction between BRS scores and getting eaten on HRV was found (β = 3.26, *SE* = 1.58, *t* = 2.06, *p* = .048) with a CI ranging between 0.18 to 6.54. These results suggest that the influence of BRS scores on HRV is higher when participants are being eaten by the shark.

Table 2. Effects on Heart Rate (HR)

Predictor	*Estimates (β)*	*SE*	*t-value*	*p*
difficulty	-0.19	0.37	-0.52	.60
eaten	0.40	0.47	0.85	.40
BRS score	0.63	2.17	0.29	.77

Note. Significance codes: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 3. Effects on Heart Rate Variability (SDNN)

Predictor	*Estimates (β)*	*SE*	*t-value*	*p*
difficulty	0.11	1.31	0.08	.93
eaten	-2.3	1.74	-1.32	.20
BRS score	-0.62	2.55	-0.24	.81

Note. Significance codes: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Figure 7

Effects of Resilience on HR

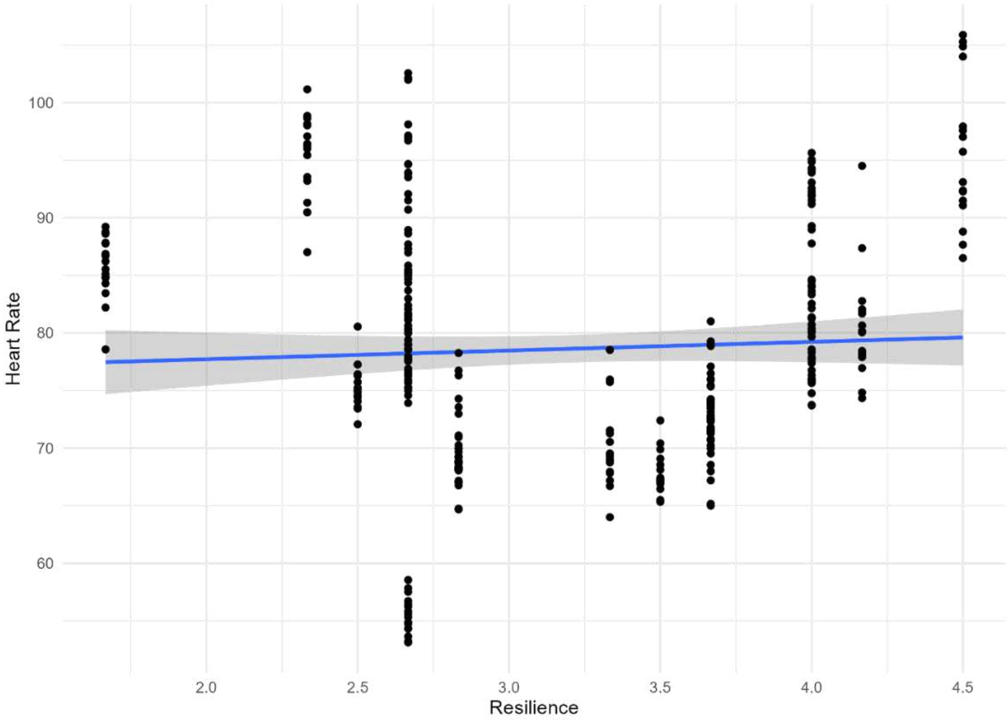
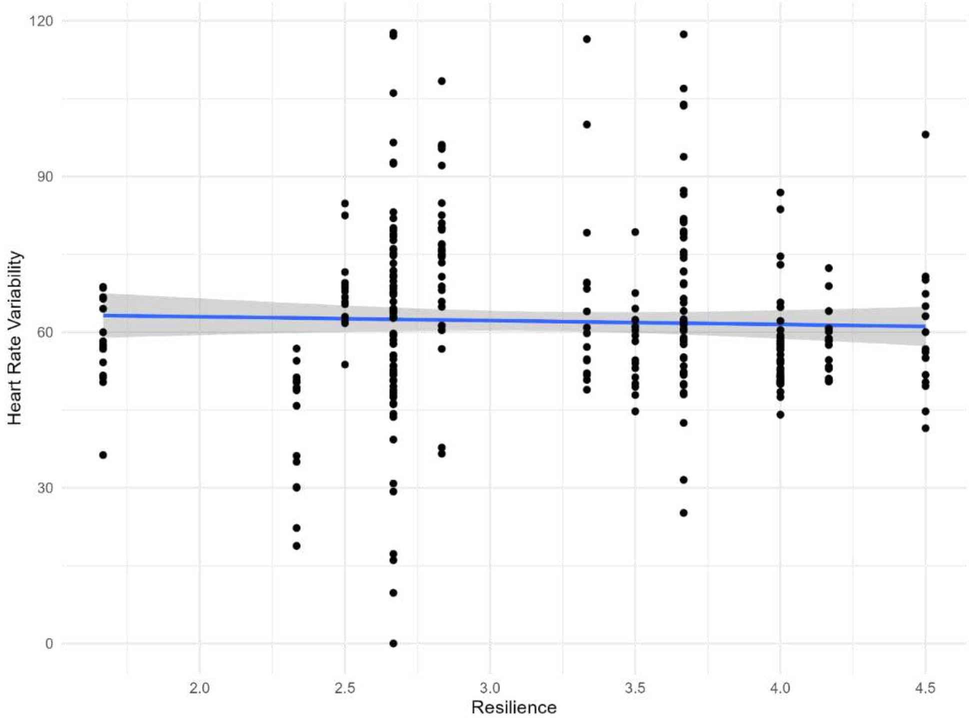


Figure 8

Effects of Resilience on HRV



The Effect of Resilience on Attribution

Results showed to be non-significant in regard to the effect of resilience on participant's reported attribution (β = -0.01, *SE* = 0.13, *t* = -0.02, *p* = .98) with a CI ranging from -0.24 to 0.24. Resilience therefore seems to have not influenced participants attribution. On the other hand, difficulty (β = -0.34, *SE* = 0.07, *t* = -4.86, *p* < .001) CI ranging from -0.46 to -0.20, and being eaten by the shark (β = -0.40, *SE* = 0.13, *t* = -3.07, *p* < .01) CI ranging from -0.65 to 0.15both showed a significant effect on attributing the outcome, indicating that the higher the difficulty the more participants tended to attribute the outcome to luck instead of performance, as they did if they were eaten by the shark. The results showed a significant interaction between difficulty and being eaten (β = 0.20, *SE* = 0.09, *t* = 2.2, *p* = 0.03) in relation to attribution. This suggests that the effect of difficulty is stronger on attribution when participants were also eaten by the shark.

The interaction between BRS scores and difficulty (β = -0.01, *SE* = 0.07, *t* = -0.05, *p* = .95) CI ranging from -0.16 to 0.14 on attribution was non-significant, indicating resilience does not have an impact on attribution based on the difficulty of the game. Similarly, the interaction between BRS scores and being eaten by the shark (β = -0.1, *SE* = 0.13, *t* = -0.74, *p* = .47) CI ranging from -0.36 to 0.15 was also non-significant. This suggests that the effect of resilience on attribution is not influenced whether or not participants were eaten by the shark. Adding these interactions, difficulty (β = -0.34, *SE* = 0.07, *t* = -4.74, *p* < .001) CI ranging from -0.49 to 0.18 and being eaten by the shark (β = -0.39, *SE* = 0.13, *t* = -2.89, *p* = .01) CI ranging from -0.65 to -0.12 still has a significant effect on attribution, while BRS scores (β = 0.04, *SE* = 0.1, *t* = 0.31, *p* = .76) CI ranging from -0.25 to 0.31 stay non-significant. However, the interaction between difficulty and being eaten (β = 0.20, *SE* = 0.94, *t* = 2.2, *p* = .05) CI ranging from 0.01 to 0.40 is no longer significant. This suggests that the effect of difficulty on attribution is not influenced by the event of being eaten by the shark.

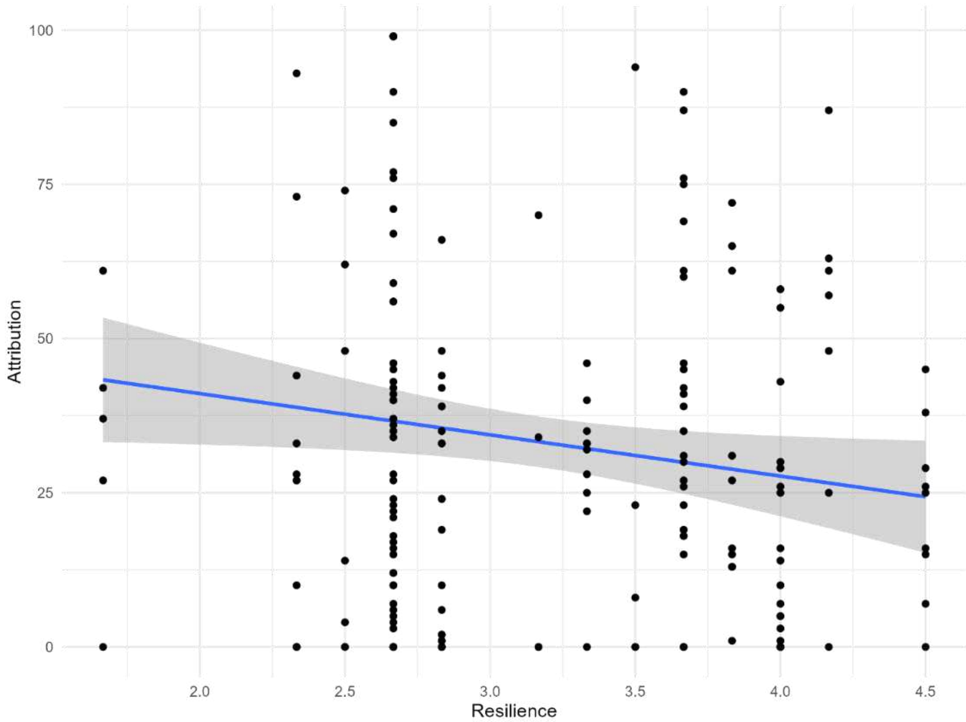
Table 4. Effects on Attribution

Predictor	*Estimates (β)*	*SE*	*t-value*	*p*
difficulty	-0.34	0.13	-3.07	<.001***
eaten	-0.40	0.13	-3.07	<.01**
BRS score	-0.01	0.13	-0.02	.98
difficulty*eaten	0.20	0.09	2.2	.03*

Note. Significance codes: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Figure 9

Effect of Resilience on Attribution



Discussion

In this thesis, the influence of resilience on stress response after experiencing a loss of control was investigated. The Brief Resilience Scale (BRS) was used to test the participants' stress resilience and its effect during acute stressful situations while playing a game. Furthermore, the influence of resilience on attribution style regarding the outcome of the game was investigated.

Participants reported higher levels of stress when facing a higher difficulty or being eaten by the shark during the game. However, biological measurements of stress, such as heart rate and heart rate variability, did not yield significant results, indicating no biological stress response in these situations. Notably, the inclusion of being eaten by the shark in the model revealed that resilience no longer influenced participants' subjective stress. However, the study found no significant interactions between resilience and difficulty or resilience and being eaten on subjective stress. This suggests that the effect of resilience on subjective stress remains consistent regardless of changes in difficulty or being eaten by the shark. It is possible that resilience may not buffer the effect of stress when being eaten by the shark, which was reported to be a strong stressor for participants. However, this study only examined the effects of resilience on subjective stress in the context of the game and further research is needed to determine its generalizability to other situations.

Regarding resilience, the results indicate that participants who showed more stress resilience also felt less stress if asked to self-report. However, resilience did not affect the biological stress response, as evidenced by no significant changes in heart rate or heart rate variability. Results did not change when the event of being eaten by the shark was included. Interestingly the interaction between resilience and getting eaten was significant in their effect on heart rate variability, suggesting that resilience had a stronger influence on HRV when participants were getting eaten. Combined with the lack of a significant effect of resilience on HRV, this could be an indicator for resilience having a modulating effect on HRV in extreme stressful situations like being eaten by the shark. This is in contrast to the findings regarding HR where resilience showed no such effect.

It was also examined if participants resilience had an influence on the attribution of the outcome of the game (“was the outcome influence by luck or performance?”). The results showed no significant effect of resilience on attribution, indicating that people's attribution style did not differ between different levels of resilience. Whereas if participants encountered a higher difficulty and were more often eaten by the shark, they attributed the outcome more towards luck than performance. Indicating that participants overall did not have an attribution bias where they attributed a negative outcome towards their own performance. Interestingly, the addition of the interaction between resilience and difficulty, as well as resilience and being eaten by the shark, was not significant in itself. However, it led to a non-significant result of the interaction between difficulty and being eaten. Additionally, resilience did not influence how participants attributed the outcome in the event of failure or based on the difficulty they encountered. The interaction between these factors on attribution appears to be complex and requires further investigation.

This rather mixed result, especially regarding the stress measurements, suggests that further studies with a higher sample size would be necessary and highly recommended to get more in-depth answers. For instance, to the question of whether resilience influences how we experience stress in the moment or if it is merely an indicator of how people deal with stress after they encounter it. This is recommended as finding no stress response on a physiological level could merely be an issue of not having enough power due to the sample size. Dickerson & Kemeny (2004) suggested that not all stress results in a physiological response, and especially studies with uncontrollable stress seem to have mixed results, with some studies finding no connection (Bohlin et al., 1986; Meine et al., 2021; Steptoe et al., 1993), while others do (Isowa et al., 2006; Peters et al., 1998).

Finding no link between internal attribution and resilience could be another hint towards the theory that resilience is a process that takes place after facing a stressor and not during it. However, some studies have found a correlation between resilience and a task-oriented or active coping style (Campbell-Sills et al., 2006; Smith et al., 2008), suggesting that resilience is linked to actively dealing with stressful situations. These findings are somewhat consistent with other studies which found no significant relationship between cortisol levels (García-León et al., 2019; Simeon et al., 2007; Zapater-Fajarí et al., 2021) and resilience during a stress task. However, it should be noted that the methods of measuring stress on a biological level differed from those used in this study.

The use of a computer game to induce stress in participants could be a promising way to ensure motivation during a stressful game and a way to test multiple participants at the same time in an economical way, as an interaction with the study coordinator is not necessary, unlike the Trier Social Stress Test (TSST; Kirschbaum et al, 1993; Allen et al., 2016), where this is often the case. Nonetheless this testing methodology would be highly recommended to also activate the biological stress response in order to rely on it as a stress-inducing method. Further studies regarding the activation of the HPA axis during the SharkBite game, could shed more light on its effects. This could be done by measuring cortisol levels during the stress game (Spencer & Deak, 2017).

Limitations

It has to be taken into account that the sample size in this study is not sufficiently large and therefore works as a limitation of this study as it is likely that the study does not have enough power (Button et al., 2013). To get a more definite answer about the relationship between stress and resilience during a stress test, studies with a larger sample size are advised. There is also the issue of little data in regards to the extremes of the BRS scale, since the small sample size lacked participants in the higher and lower extremes of resilience.

Additionally research suggests a difference in heart rate variability based on gender (Evans et al., 2011), which suggests that women tend to have a dominant parasympathetic influence on their heart rate, while men have a sympathetic influence on it. Due to this a balanced sample would be recommended, which is not the case in this study but should be taken into account for further research.

Another possible limitation could be, that the tutorial of the game was in English, and as the testing took place in a country with a different native language, some participants may have had difficulties understanding the instructions. It has to be noted though, that the tutorial was built in a way that made it impossible to proceed if the basic mechanics were not understood. Nevertheless, a translation of the game instructions might be necessary for further testing.

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Appendix

Effects on subjective stress

Model 1 including difficulty

```
REML criterion at convergence: 846.3

Scaled residuals:
          Min            1Q        Median            3Q           Max
-3.4744294103 -0.5478904327  0.0132687996  0.5720285980  3.1773780183

Random effects:
 Groups   Name                   Variance     Std.Dev.     Corr
 ID       (Intercept)            0.448291589952 0.66954580870
          subjective_difficulty_s 0.009153882551 0.09567592461 0.98939238
 Residual                        0.491068505473 0.70076280257
Number of obs: 365, groups:  ID, 24

Fixed effects:
                          Estimate     Std. Error            df t value  Pr(>|t|)
(Intercept)            0.02555004660  0.14151345357 22.95820012969 0.18055 0.8583063
subjective_difficulty_s  0.13035431211  0.04278314517 22.83852288539 3.04686 0.0057528 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Model 2 including difficulty and BRS scores

```
REML criterion at convergence: 843.7

Scaled residuals:
          Min            1Q        Median            3Q           Max
-3.5302465094 -0.5444119885  0.0201705065  0.5548105526  3.1331469378

Random effects:
 Groups   Name                   Variance     Std.Dev.     Corr
 ID       (Intercept)            0.40054369684 0.6328852162
          subjective_difficulty_s 0.01120780156 0.1058669050 1.00000000
 Residual                        0.48872933743 0.6990917947
Number of obs: 365, groups:  ID, 24

Fixed effects:
                          Estimate     Std. Error            df  t value  Pr(>|t|)
(Intercept)             0.02616520450  0.13427557212 22.26965040975  0.19486 0.8472678
subjective_difficulty_s  0.13549744133  0.04376582822 48.91722681696  3.09596 0.0032432 **
BRS_zscore             -0.27382545273  0.11863480157 24.38810983309 -2.30814 0.0297723 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Model 3 including difficulty, BRS scores and interaction term

```
REML criterion at convergence: 848

Scaled residuals:
         Min           1Q       Median           3Q          Max 
-3.5423995499 -0.5570799400  0.0193472907  0.5528317320  3.0962153329 

Random effects:
 Groups   Name                   Variance      Std.Dev.     Corr      
 ID       (Intercept)            0.40451540397 0.6360152545           
          subjective_difficulty_s 0.01197209042 0.1094170481 0.99999989
 Residual                        0.48957599589 0.6996970744           
Number of obs: 365, groups:  ID, 24

Fixed effects:
                                    Estimate     Std. Error            df  t value  Pr(>|t|)   
(Intercept)                       0.02634326219  0.13489949617 21.95609970494  0.19528 0.8469691   
subjective_difficulty_s           0.13745901519  0.04437638186 47.62237920125  3.09757 0.0032681 **
BRS_zscore                       -0.24742647153  0.13509054979 21.96588651832 -1.83156 0.0806141 . 
subjective_difficulty_s:BRS_zscore 0.01837236431  0.04443116321 47.47952173532  0.41350 0.6811008   
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Effects on subjective stress including getting eaten by the shark

Model 1 including difficulty and getting eaten and interaction term

```
REML criterion at convergence: 812

Scaled residuals:
         Min           1Q       Median           3Q          Max 
-4.0697252083 -0.4532362984  0.0235877869  0.5727769668  3.2771758269 

Random effects:
 Groups   Name                             Variance      Std.Dev.     Corr                     
 ID       (Intercept)                      0.41790488489 0.6464556326                          
          subjective_difficulty_s          0.02050781111 0.1432054856  0.31878370              
          eatenTRUE                        0.05262476409 0.2294008808  0.04520435  0.96125834  
          subjective_difficulty_s:eatenTRUE 0.02008523744 0.1417223957  0.41527709 -0.72984967 -0.88998716
 Residual                                  0.42472110872 0.6517063056                          
Number of obs: 365, groups:  ID, 24

Fixed effects:
                                   Estimate     Std. Error            df t value   Pr(>|t|)    
(Intercept)                      -0.20010257971  0.14262435411 22.91536347411 -1.40300   0.174020    
subjective_difficulty_s           0.16069543182  0.07233867105 32.34784585996  2.22143   0.033439 *  
eatenTRUE                         0.46158026469  0.09053881375 23.37776546632  5.09815 3.4923e-05 ***
subjective_difficulty_s:eatenTRUE -0.10232985150  0.08434990360 47.78423478607 -1.21316   0.231032    
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Model 2 including difficulty, getting eaten, BRS Score and interaction term

```
REML criterion at convergence: 811.3

Scaled residuals:
         Min           1Q       Median           3Q          Max
-4.1173560316 -0.4665448265  0.0179472749  0.5716874949  3.2612563295

Random effects:
 Groups   Name                              Variance      Std.Dev.     Corr
 ID       (Intercept)                       0.37592369931 0.6131261692
          subjective_difficulty_s           0.02172228846 0.1473848312  0.26916069
          eatenTRUE                         0.04391321750 0.2095548079  0.10893278  0.98666046
          subjective_difficulty_s:eatenTRUE 0.01900665721 0.1378646336  0.47851453 -0.71687606 -0.82071495
 Residual                                   0.42517162781 0.6520518598
Number of obs: 365, groups:  ID, 24

Fixed effects:
                                      Estimate      Std. Error             df  t value   Pr(>|t|)
(Intercept)                       -0.19418920304  0.13631691303 21.90390519878 -1.42454   0.168382
subjective_difficulty_s            0.16163200774  0.07285933933 28.04304679779  2.21841   0.034795 *
eatenTRUE                          0.45025357096  0.08858481739 24.18343698636  5.08274 3.3001e-05 ***
BRS_zscore                        -0.21728290144  0.12053044039 22.68583528719 -1.80272   0.084734 .
subjective_difficulty_s:eatenTRUE -0.09504085205  0.08446335833 46.97491122018 -1.12523   0.266207
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Model 3 including difficulty, getting eaten, BRS Score and interaction terms

```
REML criterion at convergence: 821.7

Scaled residuals:
         Min           1Q       Median           3Q          Max
-4.1116062382 -0.4646380815  0.0213869861  0.5772506752  3.2759982147

Random effects:
 Groups   Name                              Variance      Std.Dev.     Corr
 ID       (Intercept)                       0.38129352592 0.6174896970
          subjective_difficulty_s           0.02487543896 0.1577194946  0.24939880
          eatenTRUE                         0.05141199944 0.2267421431  0.07902373  0.88036923
          subjective_difficulty_s:eatenTRUE 0.02191630083 0.1480415510  0.47847973 -0.72958273 -0.76431213
 Residual                                   0.42659825043 0.6531448924
Number of obs: 365, groups:  ID, 24

Fixed effects:
                                                  Estimate       Std. Error              df  t value   Pr(>|t|)
(Intercept)                                 -0.194722871036  0.137423693566 21.289187273330 -1.41695   0.170965
subjective_difficulty_s                      0.161469017624  0.074222527892 16.441910487254  2.17547   0.044501 *
BRS_zscore                                  -0.220265004272  0.136706508110 20.840183956190 -1.61123   0.122173
eatenTRUE                                    0.450272235169  0.091073836570 21.800353276985  4.94403 6.1832e-05 ***
subjective_difficulty_s:BRS_zscore          -0.024890848690  0.071964831163 15.970467526390 -0.34588   0.733951
subjective_difficulty_s:eatenTRUE           -0.094493428633  0.086211531548 34.029322618178 -1.09606   0.280747
BRS_zscore:eatenTRUE                        -0.001403341176  0.090398258376 21.798889448453 -0.01552   0.987755
subjective_difficulty_s:BRS_zscore:eatenTRUE  0.028060692019  0.085055377689 36.068042636156  0.32991   0.743376
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Effects on heart rate (mean HR)

Model 1 including difficulty

```
REML criterion at convergence: 1706.7

Scaled residuals:
         Min           1Q       Median           3Q          Max 
-3.6199035646 -0.5508464112 -0.0772858880  0.4900587637  5.4613128231 

Random effects:
 Groups   Name                   Variance      Std.Dev.     Corr      
 ID       (Intercept)            112.8983241973 10.6253623090           
          subjective_difficulty_s   0.1084228003  0.3292761763 1.00000000
 Residual                         11.5049297239  3.3918917618           
Number of obs: 305, groups:  ID, 20

Fixed effects:
                            Estimate     Std. Error             df  t value Pr(>|t|)    
(Intercept)             78.69494732228  2.38384497568 19.00268063256 33.01177  < 2e-16 ***
subjective_difficulty_s  0.08413695018  0.21207837758 64.61887885581  0.39673  0.69288    
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Model 2 including difficulty and BRS Score

```
REML criterion at convergence: 1703.2

Scaled residuals:
         Min           1Q       Median           3Q          Max 
-3.6248080772 -0.5526157672 -0.0842565893  0.4853001715  5.4617476898 

Random effects:
 Groups   Name                   Variance      Std.Dev.     Corr      
 ID       (Intercept)            117.9747951724 10.8616202830           
          subjective_difficulty_s   0.1020165383  0.3194002791 1.00000000
 Residual                         11.5093574281  3.3925443885           
Number of obs: 305, groups:  ID, 20

Fixed effects:
                            Estimate     Std. Error             df  t value Pr(>|t|)    
(Intercept)             78.72212533425  2.43815618861 18.21073456438 32.28756  < 2e-16 ***
subjective_difficulty_s  0.08198068782  0.21153360240 66.65330301506  0.38755  0.69958    
BRS_zscore               0.63352057879  2.17385065413 18.43722832677  0.29143  0.77398    
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Model 3 including difficulty, BRS Score and interaction term

```
REML criterion at convergence: 1704.6

Scaled residuals:
          Min            1Q        Median            3Q           Max
-3.6099064151 -0.5512427021 -0.0845092458  0.4847072761  5.4531624611

Random effects:
 Groups   Name                     Variance      Std.Dev.     Corr
 ID       (Intercept)              118.7124045987 10.8955222270
          subjective_difficulty_s    0.1128068938  0.3358673754 1.00000000
 Residual                           11.5452544991  3.3978308520
Number of obs: 305, groups:  ID, 20

Fixed effects:
                                        Estimate        Std. Error               df  t value Pr(>|t|)
(Intercept)                         78.7207356869046  2.4460600483774 18.0024229872056 32.18267  < 2e-16 ***
subjective_difficulty_s              0.0812095706308  0.2161378154431 63.3092892589862  0.37573  0.70837
BRS_zscore                           0.6234170540116  2.3102149103407 18.0031410066514  0.26985  0.79034
subjective_difficulty_s:BRS_zscore -0.0004270802082  0.2055595919730 64.8304705546917 -0.00208  0.99835
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Effects on heart rate (mean HR) including getting eaten

Model 1 including difficulty and getting eaten and interaction term

```
REML criterion at convergence: 1700.2

Scaled residuals:
          Min            1Q        Median            3Q           Max
-3.3896081511 -0.5223482725 -0.0583076713  0.4840644348  5.4988207349

Random effects:
 Groups   Name                             Variance      Std.Dev.     Corr
 ID       (Intercept)                      109.5495939373 10.4665941900
          subjective_difficulty_s            0.2083072093  0.4564068463 -0.98860887
          eatenTRUE                          0.6410859694  0.8006784432  0.12041677  0.03036627
          subjective_difficulty_s:eatenTRUE   1.1206614929  1.0586130043  0.96704013 -0.99434708 -0.13632335
 Residual                                   11.1971112965  3.3462084957
Number of obs: 305, groups:  ID, 20

Fixed effects:
                                    Estimate    Std. Error            df  t value Pr(>|t|)
(Intercept)                       78.4341864807  2.3603988162 18.8660082378 33.22921  < 2e-16 ***
subjective_difficulty_s           -0.1978905037  0.3747873517 81.5880880151 -0.52801  0.59893
eatenTRUE                          0.3996032599  0.4752551264 23.5104856592  0.84082  0.40892
subjective_difficulty_s:eatenTRUE  0.3377903575  0.4971626254 38.6928457899  0.67944  0.50091
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Model 2 including difficulty, getting eaten, BRS Score and interaction term

```
REML criterion at convergence: 1697

Scaled residuals:
         Min           1Q       Median           3Q          Max 
-3.3870396681 -0.5203925314 -0.0535919777  0.4874678556  5.4978139503 

Random effects:
 Groups   Name                              Variance       Std.Dev.      Corr
 ID       (Intercept)                       114.3128914867 10.6917206981
          subjective_difficulty_s             0.1848373550  0.4299271508 -1.00000000
          eatenTRUE                           0.6231669305  0.7894092288  0.08418155 -0.08418155
          subjective_difficulty_s:eatenTRUE   1.0287452758  1.0142708099  0.97770135 -0.97770135 -0.12695033
 Residual                                    11.2145147354  3.3488079574
Number of obs: 305, groups:  ID, 20

Fixed effects:
                                      Estimate    Std. Error            df  t value Pr(>|t|)    
(Intercept)                       78.4510837542  2.4116249471 18.2435721441 32.53038  < 2e-16 ***
subjective_difficulty_s           -0.1952417716  0.3735632114 89.0128399886 -0.52265  0.60252    
eatenTRUE                          0.4047487016  0.4753747544 22.7718698728  0.85143  0.40340    
BRS_zscore                         0.3738200832  2.0174417123 18.6188401627  0.18529  0.85500    
subjective_difficulty_s:eatenTRUE  0.3313515556  0.4940822775 40.5499465146  0.67064  0.50625    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Model 3 including difficulty, getting eaten, BRS Score and additional interaction terms

```
REML criterion at convergence: 1696

Scaled residuals:
         Min           1Q       Median           3Q          Max 
-3.3347312679 -0.5388089937 -0.0592946809  0.5152245411  5.5134102501 

Random effects:
 Groups   Name                              Variance       Std.Dev.      Corr
 ID       (Intercept)                       115.5367626140 10.7488028456
          subjective_difficulty_s             0.2199792047  0.4690194076 -1.00000000
          eatenTRUE                           0.4216440696  0.6493412582  0.11526606 -0.11526606
          subjective_difficulty_s:eatenTRUE   1.1620041057  1.0779629426  0.97806450 -0.97806450 -0.09417617
 Residual                                    11.2809736443  3.3587160708
Number of obs: 305, groups:  ID, 20

Fixed effects:
                                                  Estimate     Std. Error             df  t value Pr(>|t|)    
(Intercept)                                    78.50174970759  2.42516043457 17.87540081591 32.36971  < 2e-16 ***
subjective_difficulty_s                        -0.21144245975  0.37703234987 75.87013082348 -0.56081  0.57658    
BRS_zscore                                      0.33317225785  2.28845673989 17.81380327089  0.14559  0.88588    
eatenTRUE                                       0.38329706447  0.46752296720 24.74408575383  0.81985  0.42013    
subjective_difficulty_s:BRS_zscore             -0.09276224572  0.34423678922 69.16046705307 -0.26947  0.78837    
subjective_difficulty_s:eatenTRUE               0.32080309626  0.50645757662 37.16772043606  0.63343  0.53033    
BRS_zscore:eatenTRUE                            0.60301368622  0.43383402805 24.59751561466  1.38996  0.17699    
subjective_difficulty_s:BRS_zscore:eatenTRUE    0.08166338298  0.47176635710 35.61337376417  0.17310  0.86355    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Effects on heart rate variability (SDNN)

Model 1 including difficulty

```
REML criterion at convergence: 2441.8

Scaled residuals:
         Min           1Q       Median           3Q          Max
-4.9737072441 -0.4461187668  0.0177724558  0.4975957781  3.8408456457

Random effects:
 Groups   Name                    Variance      Std.Dev.     Corr
 ID       (Intercept)             128.729845067 11.345917551
          subjective_difficulty_s   6.654501554  2.579632058 -0.09695873
 Residual                         146.176516751 12.090348082
Number of obs: 305, groups:  ID, 20

Fixed effects:
                            Estimate    Std. Error           df  t value   Pr(>|t|)
(Intercept)             62.2409040886  2.6321627003 18.9224846728 23.64630 1.6379e-15 ***
subjective_difficulty_s  0.8271581509  0.9261850777 19.0621706990  0.89308    0.38295
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Model 2 including difficulty and BRS Score

```
REML criterion at convergence: 2438.1

Scaled residuals:
         Min           1Q       Median           3Q          Max
-4.9755206668 -0.4475487288  0.0204634796  0.4980410333  3.8418333584

Random effects:
 Groups   Name                    Variance      Std.Dev.     Corr
 ID       (Intercept)             135.864803053 11.656105827
          subjective_difficulty_s   6.660406527  2.580776342 -0.08587863
 Residual                         146.173876726 12.090238903
Number of obs: 305, groups:  ID, 20

Fixed effects:
                            Estimate    Std. Error           df  t value   Pr(>|t|)
(Intercept)             62.2167610177  2.7011921204 17.9268381495 23.03308 9.1047e-15 ***
subjective_difficulty_s  0.8338037678  0.9264683474 19.0725538725  0.89998    0.37935
BRS_zscore              -0.6161190715  2.5480735653 17.9570332062 -0.24180    0.81168
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Model 3 including difficulty, BRS Score and interaction term

```
REML criterion at convergence: 2436.3

Scaled residuals:
          Min            1Q        Median            3Q           Max 
-4.9778477756 -0.4456103364  0.0297261102  0.5022193731  3.8227736864 

Random effects:
 Groups   Name                   Variance      Std.Dev.     Corr       
 ID       (Intercept)            135.398793840 11.636098738            
          subjective_difficulty_s   7.362739348  2.713436815 -0.09659310
 Residual                        146.263545988 12.093946667            
Number of obs: 305, groups:  ID, 20

Fixed effects:
                                    Estimate    Std. Error            df  t value   Pr(>|t|)    
(Intercept)                       62.2177559648  2.6970371137 17.9180657681 23.06893 8.9601e-15 ***
subjective_difficulty_s            0.8833078129  0.9525353912 18.8790006514  0.92732    0.36546    
BRS_zscore                        -0.6665610841  2.5470509039 17.9130444747 -0.26170    0.79654    
subjective_difficulty_s:BRS_zscore  0.3616495262  0.9029983367 19.2881464113  0.40050    0.69319    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Effects on heart rate variability (SDNN) including being eaten

Model 1 including difficulty and getting eaten and interaction term

```
REML criterion at convergence: 2423.4

Scaled residuals:
          Min            1Q        Median            3Q           Max 
-4.8992657308 -0.4718494234 -0.0271325010  0.5161004408  3.5284196591 

Random effects:
 Groups   Name                          Variance      Std.Dev.     Corr                         
 ID       (Intercept)                    99.137813204  9.956797337                              
          subjective_difficulty_s         2.203306911  1.484354038 -0.99536407                  
          eatenTRUE                       4.310660549  2.076213031  0.83784120 -0.78145285      
          subjective_difficulty_s:eatenTRUE  24.475108269  4.947232385  0.34425311 -0.43295563 -0.22411648
 Residual                               138.165070085 11.754363874                              
Number of obs: 305, groups:  ID, 20

Fixed effects:
                                  Estimate    Std. Error            df  t value   Pr(>|t|)    
(Intercept)                      63.2431477197  2.4616066425 16.4701110785 25.69182 1.0086e-14 ***
subjective_difficulty_s           0.1303269135  1.3042428715 89.4889824015  0.09993    0.92063    
eatenTRUE                        -2.1990068650  1.6231075675 54.3908545548 -1.35481    0.18108    
subjective_difficulty_s:eatenTRUE  1.7002091792  1.9331153338 30.1340874542  0.87952    0.38608    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Model 2 including difficulty, getting eaten, BRS Score and interaction term

```
REML criterion at convergence: 2418.5

Scaled residuals:
          Min            1Q        Median            3Q           Max
-4.9206469866 -0.4798343853 -0.0205549164  0.5138449738  3.5373357497

Random effects:
 Groups   Name                              Variance      Std.Dev.     Corr
 ID       (Intercept)                        91.718478378  9.576976474
          subjective_difficulty_s             2.503699528  1.582308291 -0.98784893
          eatenTRUE                          12.258210341  3.501172709  0.92673244 -0.85707801
          subjective_difficulty_s:eatenTRUE  24.106790099  4.909866607  0.34753858 -0.48904495 -0.03022631
 Residual                                   137.602984391 11.730429847
Number of obs: 305, groups:  ID, 20

Fixed effects:
                                      Estimate     Std. Error            df   t value    Pr(>|t|)
(Intercept)                      63.2628245473  2.3812530151 15.7124861418 26.56703 1.7541e-14 ***
subjective_difficulty_s           0.1101018526  1.3063399318 79.9797389962  0.08428    0.93304
eatenTRUE                        -2.2948110098  1.7363088788 24.2579189591 -1.32166    0.19861
BRS_zscore                       -3.0742990829  2.1904635047 14.3331740207 -1.40349    0.18176
subjective_difficulty_s:eatenTRUE  1.6445674071  1.9250646218 30.1773197283  0.85429    0.39967
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Model 3 including difficulty, getting eaten, BRS Score and additional interaction terms

```
REML criterion at convergence: 2406.5

Scaled residuals:
          Min            1Q        Median            3Q           Max
-4.9165456857 -0.4920853422  0.0053612970  0.5151427265  3.5220388589

Random effects:
 Groups   Name                              Variance      Std.Dev.     Corr
 ID       (Intercept)                        91.810363186  9.581772445
          subjective_difficulty_s             2.517792356  1.586755292 -0.98439977
          eatenTRUE                          10.136464256  3.183781440  0.88767636 -0.79281133
          subjective_difficulty_s:eatenTRUE  24.519958186  4.951763139  0.30750608 -0.47012931 -0.16519036
 Residual                                   136.879482953 11.699550545
Number of obs: 305, groups:  ID, 20

Fixed effects:
                                               Estimate      Std. Error             df   t value     Pr(>|t|)
(Intercept)                                 63.49412262621  2.38528271367 15.93675825698 26.61912 1.2287e-14 ***
subjective_difficulty_s                      0.04782548856  1.30513652580 76.72756221359  0.03664   0.970864
BRS_zscore                                  -2.56139155266  2.23091900626 15.38734774998 -1.14813   0.268451
eatenTRUE                                   -2.37494044475  1.71175238006 30.92387535347 -1.38743   0.175228
subjective_difficulty_s:BRS_zscore          -0.21332207141  1.18944860427 72.37558187719 -0.17935   0.858168
subjective_difficulty_s:eatenTRUE            1.58851909627  1.94021191464 29.16279812243  0.81873   0.419578
BRS_zscore:eatenTRUE                         3.26418297679  1.58211843061 28.93094110004  2.06317   0.048172 *
subjective_difficulty_s:BRS_zscore:eatenTRUE 0.59844719599  1.79811003614 26.96874496255  0.33282   0.741844
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Effects on attribution including getting eaten

Model 1 including difficulty and getting eaten and interaction term

```
REML criterion at convergence: 823.4

Scaled residuals:
          Min            1Q        Median            3Q           Max
-2.8274200963 -0.5911856714 -0.0021153182  0.5357702799  3.6883525090

Random effects:
 Groups   Name                             Variance      Std.Dev.     Corr
 ID       (Intercept)                      0.38260779185 0.6185529822
          subjective_difficulty_s          0.01797880486 0.1340850657 -0.34638357
          eatenTRUE                        0.25387376563 0.5038588747 -0.28246943 -0.41947767
          subjective_difficulty_s:eatenTRUE 0.03697529790 0.1922896199  0.37018704  0.55267083 -0.04978953
 Residual                                  0.40064873033 0.6329681906
Number of obs: 365, groups:  ID, 24

Fixed effects:
                                      Estimate     Std. Error             df  t value  Pr(>|t|)
(Intercept)                         0.24317204924  0.13837645840 14.18979525849  1.75732  0.100408
subjective_difficulty_s            -0.33912208859  0.07007871891 39.17429742655 -4.83916 2.059e-05 ***
eatenTRUE                          -0.39726425511  0.13016292928 18.06411456760 -3.05205  0.006841 **
subjective_difficulty_s:eatenTRUE   0.20077053515  0.09207984355 44.45840090968  2.18040  0.034563 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Model 2 including difficulty, getting eaten, BRS Score and interaction term

```
REML criterion at convergence: 825.6

Scaled residuals:
          Min            1Q        Median            3Q           Max
-2.8268832895 -0.5896856433  0.0016278757  0.5366782710  3.6918982134

Random effects:
 Groups   Name                             Variance      Std.Dev.     Corr
 ID       (Intercept)                      0.41093234187 0.6410400470
          subjective_difficulty_s          0.01730249904 0.1315389640 -0.32142854
          eatenTRUE                        0.25012771167 0.5001276954 -0.28818284 -0.42101167
          subjective_difficulty_s:eatenTRUE 0.03616208607 0.1901633142  0.35133983  0.59590311 -0.06353060
 Residual                                  0.40065816827 0.6329756459
Number of obs: 365, groups:  ID, 24

Fixed effects:
                                      Estimate      Std. Error               df  t value   Pr(>|t|)
(Intercept)                         0.244740818262  0.142663826149 13.454655337738  1.71551  0.1091766
subjective_difficulty_s            -0.339763819861  0.069889328583 40.534207649007 -4.86145 1.7904e-05 ***
eatenTRUE                          -0.398694798955  0.129734170550 18.165733433137 -3.07317  0.0065011 **
BRS_zscore                         -0.002909322208  0.130006327757 15.592308677811 -0.02238  0.9824301
subjective_difficulty_s:eatenTRUE   0.201408152005  0.091907425855 45.120144909305  2.19142  0.0336242 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Model 3 including difficulty, getting eaten, BRS Score and additional interaction terms

```
REML criterion at convergence: 833.8

Scaled residuals:
        Min          1Q      Median          3Q         Max
-2.8226685275 -0.5710948338 -0.0076010367  0.5430844030  3.6640261511

Random effects:
 Groups   Name                              Variance     Std.Dev.     Corr
 ID       (Intercept)                       0.39604806759 0.6293235000
          subjective_difficulty_s           0.02201019667 0.1483583387 -0.29912270
          eatenTRUE                         0.27203985455 0.5215743998 -0.28366464 -0.43773408
          subjective_difficulty_s:eatenTRUE 0.04420897236 0.2102592979  0.33936897  0.39680014 -0.08968982
 Residual                                   0.40051675760 0.6328639329
Number of obs: 365, groups:  ID, 24

Fixed effects:
                                               Estimate      Std. Error              df  t value   Pr(>|t|)
(Intercept)                                  0.236980465431  0.140702218935 13.782471924270  1.68427 0.11462998
subjective_difficulty_s                     -0.339741568522  0.071721577024 13.200312466311 -4.73695 0.00037273 ***
BRS_zscore                                   0.042917146110  0.139587940489 13.423045784216  0.30746 0.76321475
eatenTRUE                                   -0.385818553769  0.133656346103 17.319950026627 -2.88665 0.01010664 *
subjective_difficulty_s:BRS_zscore          -0.003686503416  0.069549525123 12.973581812961 -0.05301 0.95853507
subjective_difficulty_s:eatenTRUE            0.198564666263  0.094535507786 17.404261233347  2.10042 0.05055433 .
BRS_zscore:eatenTRUE                        -0.098275791923  0.131955753398 16.674373085421 -0.74476 0.46678291
subjective_difficulty_s:BRS_zscore:eatenTRUE -0.037621305040  0.090578118796 15.020773109881 -0.41535 0.68376060
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

German Abstract

Die subjektiv wahrgenommene Kontrolle ist ein entscheidender Faktor für das Wohlbefinden. Sie kann als Schutzfaktor gegen Stress wirken, die Lebenserwartung älterer Menschen erhöhen und sich positiv auf die psychische Gesundheit auswirken. Während Resilienz im Allgemeinen als Schutzfaktor gegen Stress angesehen wird, lieferte dessen Auswirkungen auf akute Stresssituationen uneinheitliche Studienergebnisse. Die Untersuchung der Auswirkungen von Kontrollverlust auf das Stressniveau kann unser Verständnis von Resilienz verbessern. In dieser Studie spielten 24 Teilnehmende ein Browserspiel über 16 Runden und erlebten einen zunehmenden Kontrollverlust. Während des Spiels wurde das Stressniveau der Teilnehmenden anhand von Fragebögen zu subjektivem Stress, sowie einer Herzfrequenz-Messung festgestellt. Zur Bestimmung der Resilienz der Teilnehmenden wurde die deutsche Version der Brief Resilience Scale (BRS) verwendet. Die Studie ergab, dass das subjektive Stressniveau der Teilnehmenden höher war, wenn sie einen größeren Kontrollverlust erlebten. Der Effekt zeigte sich jedoch weder bei der Herzfrequenz noch bei der Herzfrequenzvariabilität. Außerdem hatten die BRS-Werte keinen Einfluss auf die Herzfrequenz oder die Herzfrequenzvariabilität, sondern nur auf das subjektive Stressempfinden. Diese Ergebnisse deuten darauf hin, dass die Teilnehmenden subjektiven Stress empfanden, aber keine physiologische Reaktion auf diesen Stress zeigten. Die BRS-Werte hatten ebenfalls keinen Einfluss auf die Attribution des Spielergebnisses durch die Teilnehmenden.