universität wien

MASTERARBEIT / MASTER'S THESIS

Titel der Masterarbeit / Title of the Master's Thesis

„Experimental induction of social isolation: the effects on emotional states and stress responses"

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, 2021 / Vienna 2021

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 UG2002
Betreut von / Supervisor:	Assoz. Prof. Giorgia Silani, Privatdoz. PhD

Acknowledgments:

First, I want to thank my thesis advisor PhD Girogia Silani for her support. She was always open for questions and gave important recommendations. Not only on a professional level it was great to have PhD Girogia Silani as a supervisor also on a personal level she was constantly very friendly and helpful.

Many thanks go also to Ana Stijovic who gave me the chance to participate in her great PhD study. She was a constant help and supportive with every little problem that appeared in the process of writing my thesis. I thank you very much it was a pleasure working with you on the project.

I want to thank my mother for her unconditional support throughout my whole educational career. Your encouragement and strong belief in my skills was always a strong motivator and reassurance. In addition, I want to thank my brothers for leading me to Vienna and always supporting me with all little things that I needed help with as a little sister.

A big thank you goes to my very precious friends. Tatiana Corvisier thank you for your very motivational words, always believing in me and your valuable feedback. Paulina Wiegand, I want to thank you for your help in the process of writing my thesis and your great comments. Antonia Schröder I thank you for your constant emotional support and encouragement throughout the whole process. I also want to thank every other friend who always supported and motivated me on my way to my graduation.

Lastly, I want to thank Ludovico Lombardo your help was essential for me while writing my thesis and I thank you so very much. Your professional advice and personal support are encouraging and so appreciated.

I consider myself very lucky having had so much support on my way to become a Psychologist. Thank you very much!

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Experimental induction of social isolation: the effects on emotional states and stress responses

"A person is a person through other persons; you can't be human in isolation; you are human only in relationships" - Desmond Tutu.

Social isolation is defined as the absence of relationships, interactions and contacts with family, friends and neighbours on an individual and with society on a broader level (Berg & Cassells, 1992) and is experienced very adversely by humans and other social beings. The lack of interpersonal bonds of humans often co-occurs with worse health and worse well-being (Baumeister & Leary, 1995; Hawkley & Cacioppo, 2003; Leigh-Hunt et al., 2017) and the feeling of loneliness increases the risk of premature mortality by twenty-six percent (J. T. Cacioppo & Cacioppo, 2018a; 2018b). Consequently, humans avoid being socially isolated. Social affiliation can be considered as a basic need and leads to biologically triggered attachment behaviour to keep the "social homeostasis" (Matthews & Tye, 2019). Social behaviour might be based on genetically specified programs that detect key stimuli and evoke certain behaviours (Matthews & Tye, 2019) acting similar like other survival circuits that can generate a specific response pattern (Le Doux, 2012) and motivate individuals to affiliate with other people. The evolutionary perspective connects with this view. Already in the early stages of life, social contact is essential. The attachment from a child to the primary caregiver plays an important role in humans, for social cognition and the preparation for collaborative existence (Fonagy & Target, 2005). While shaping certain brain structures, it sets the strong desire in humans to belong and triggers the motivation to form relationships with others. Belonging to a social group is essential for the survival of humans and other social species because organisms are highly dependent on each other for meeting their basic needs (Dunbar, 2016). Being part of a group is a great survival benefit for humans, whereas isolation comes with less support and less social resources from others. In consequence, humans show automatic adaptive responses to loneliness, including a higher alertness of the stress regulating system, a lower consistency of sleep and an increased inflammatory activity (J. T. Cacioppo & Cacioppo, 2018a). These reactions help to survive in hazardous situations that an individual needs to confront alone. In the long term, these responses, however, can lead to worse health outcome since a continuous elevated stress response is connected to a lot of negative health consequences (Baba et al., 1998; Juster et al., 2010). This indicates that social isolation represents an aversive state, which is connected to an increased physiological stress-response inducing a stressful state for the organism through accelerated cortisol release. (Hawkley et al., 2012). It

further impacts affective feelings in humans. Social facets as social exclusion, disconnection or rejection cause similar responses as physical pain (Eisenberger, 2015; 2012; Eisenberger et al., 2003) implying that missing interactions are felt very aversively. Strong evidence on emotions also comes also from prison studies showing that individuals being in solitary confinement experience affective disorders including anxiety and depression (Gamman, 2001 as cited in Smith, 2006; Haney, 2003). Already after ten hours of total social isolation, individuals experience feelings of loneliness and an increased desire for social interactions. As visible in neuronal images, the substantia nigra (SN) and ventral tegmental area (VTA) show distinct activation to social deprived cues as short-term isolation (Tomova et al., 2020). The VTA and SN are cortical regions connected to reward processes (O'Doherty, 2004) indicating that social isolation elicits the motivation to look for social contact after a ten-hour isolation period comparable to cravings like hunger (Tomova et al., 2020). This unique study focusing on forced short-term isolation indicates an immediate response to social isolation within humans.

Nevertheless, research focusing on acute social isolation and its outcome especially on stress and mood is still scarce, therefore the aim of this thesis is to examine short-term effects, of induced social isolation and the resulting consequences on emotional states and the physical stress response. Leading to the two research questions 1. Does an experimentally induced state of social isolation (lasting for eight hours) lead to an increase in negative mood over time and in comparison to the neutral state? 2. Does the experimentally induced social isolation (lasting for eight hours) lead to an increase in the physiological stress-response (cortisol) over time and in comparison to the neutral state? The two main outcomes of interest include changes in perceived and physical stress responses (cortisol levels) and mood variances. In addition, effects on executive cognitive abilities, motor speed, subjective desires for social contact, physical arousal (heart rate) and motivational desires (food, phone, internet) are examined. Within this experiment social isolation was induced in a controlled setting over eight hours with the main focus relying on the examination of cortisol levels and the mood response over time and in comparison to the neutral condition.

2. Social isolation

Social isolation is lack of connections with others and the loss of belonging to a group (Berg & Cassells, 1992). It can be voluntary or involuntary and is often connected with the feeling of loneliness. Social isolation can be divided into objective and subjective isolation, where the first is a quantifiable lack of human contact and the second describes closeness to the members of one's social network. Both components show a highly correlation with each other (Taylor et al., 2016). Objective isolation can impact perceived isolation, which is often

equated with loneliness (Hawkley et al., 2008; Ruiz, 2007). Perceived social isolation comprises mainly the quality whereas objective social isolation the quantity of social connections (Hawkley et al., 2008). Even though both components interact with each other, loneliness can be impacted by factors unrelated to objective social isolation, including genetics (Boomsma et al., 2005), childhood environment (Bartels et al., 2008), sociodemographic factors (Hawkley et al., 2009) and social needs (Dykstra & Fokkema, 2007).

Loneliness has a strong impact on health which might explain the strong focus within the research community. The mortality risk of lonely individuals rises by forty-five percent. In comparison, individuals living in a polluted area have a five percent higher risk, obesity results in a twenty percent higher risk, and an excessive alcohol consumption increases mortality risk by thirty percent. Loneliness represents the most hazardous impact for humans (Holt-Lunstad et al., 2010). In a further meta-analysis, similar findings were validated, social isolation led to twenty-nine percent, loneliness to twenty-six percent and living alone to thirty-two percent higher mortality risk. In this meta-analysis, no differences between objective and subjective isolation could be found and the results were independent from gender or world region, even though an influence due to previous health conditions was apparent. Furthermore, the mortality risk was more predictive for individuals under sixty-five (Holt-Lunstad et al., 2015). Solely objective social isolation caused by the death of the spouses was shown to increase the chances of premature death by twenty-five percent (Elwert & Christakis, 2008).

The better the social network of friends the smaller the chance of getting sick and the quicker the ability of recovery and longevity (Bzdok & Robin, 2020; Pinquart & Duberstein, 2010; Reblin & Uchino, 2008; Smith & Christakis, 2008). For the mortality risk of cardiovascular diseases, the frequency of social support and the quality of social integration into the social network comprise the two most influencing variables (Holt-Lunstad et al., 2010). Inferring from the various studies, both subjective and objective isolation impact humans and play a crucial role in their health.

2.1. Evolutionary perspective

Since social isolation has so much influence on many levels in social beings, researchers claim that the need to belong and interact with people evolved in an evolutionary manner (J. T. Cacioppo & S. Cacioppo, 2018a; J. T. Cacioppo & Patrick, 2009). The evolutionary point of view argues that humans and other social species have a higher chance of survival and reproduction if they live in groups and develop genetic and biological mechanisms to affiliate with others.

Animal studies strengthen the view of biological predisposition. One of the earliest studies on this, which is still very important in psychology research, confirmed that an infant monkey, when separated from his mother and put in a cage with two surrogate mothers, favoured the soft coating surrogate over the wired surrogate which provided food (Harlow, 1958). This finding first implicated that the need for belonging and affection plays a very prominent role for social organisms, taking precedence over food supply. In another study with young monkeys, different effects of isolation were addressed, validating that partially or totally isolated monkeys in the first six months of life showed long-lasting consequences as self-mutilation behaviour, repetitive cycling, staring and severely disturbed behaviour. After the isolation, a reintegration with fellow monkeys did not succeed anymore (Harlow et al., 1965). These findings indicate that social experiences are crucial for the well-being and future interactions.

The evolutionary perspective is also especially discussed regarding humans, as toddlers have a similar cognitive repertoire for engaging with their environmental surroundings as chimpanzees but possess more cognitive skills to interact in the social world (Herrmann, et al., 2007). Large metabolic intensive brains are shown to be linked with social complexity and evolved differently across species according to social demands (Dunbar & Shultz, 2007). Linked to that is the feeling of loneliness in humans which is strongly correlated to social isolation (Hawkley et al., 2008; Ruiz, 2007; Taylor et al., 2016). Loneliness can be compared to a deprived state that signals the individual to seek for social bonds. It embraces an unfulfilled need, which leads to specific behaviour with the aim to satisfy it (J. T. Cacioppo & S. Cacioppo, 2018a; J. T. Cacioppo & Patrick, 2009).

Evidence from other biological studies (J. T. Cacioppo & S. Cacioppo 2018a) underlines the adaptive value of social affiliation. The body reacts with short-term adaptive responses in consequence of social isolation (J. T. Cacioppo & S. Cacioppo 2018a). These body reactions have a short-term survival benefit but can be maladaptive for humans if experienced chronically (Baba et al., 1998; Juster et al., 2010), explaining the increased mortality risk (Holt-Lunstad et al., 2015; Holt-Lunstad et al., 2010).

The brain also shows adaptive adjustments to circumstances of social isolation. One very prominent finding shows that the same brain areas (anterior insular and cingulate cortex) that are activated during pain are also involved when being lonely (Kross et al., 2011). This indicates that missing social interactions can be experienced as aversive as other pain triggering stimuli as they cause similar reactions as the perception of physical pain (Eisenberger, 2015). The feeling of social pain during isolation may have evolved to promote and motivate

social interaction, which is crucial for reproduction, gene transfer and to diminish selfish anti-social behaviours in groups (J. T. Cacioppo & Patrick, 2009). Social content might be evolutionarily connected to the pain system due to its survival value (Eisenberger et al., 2003). The perception of social pain due to loneliness might result in affiliation behaviour, so individuals are better protected in threatful situations. The feeling of harm to oneself, similar to physical pain leads to adaptive behaviour which reduces the risk of getting injured and enhances survival. However, other recent studies also show that social isolation is a more complex process and is not equivalent to the same neuronal activations as physical pain but connected to complex neural activities (S. Cacioppo et al., 2013).

In summary, inferring from the evolutionary point of view, it becomes evident that human beings are fundamentally motivated to attach and belong to others and retain interpersonal bonds. Social affiliation helps to survive, reproduce and to care better for the offspring.

2.2. Social isolation as a motivator

As described from the evolutionary perspective, social isolation is an aversive state, which triggers the drive to reinstate the social homeostasis (Matthews & Tye, 2019) when deprived. It further inflicts socially motivated behaviour and can be driven by positive and negative valence to either avoid social isolation or to seek for a social reward. After twenty-four hours of isolation, dopaminergic neurons in the dorsal raphe nucleus (DRN), motivate rodents to affiliate with others (Matthews et al., 2016). It is not clear if the same neuronal areas are involved in social and non-social motivated behaviour, but research showed that social isolation leads to the activation of the ventral striatum, an area that is involved in the reward processing in humans (O'Doherty, 2004). The reward system includes two main pathways, the mesolimbic dopamine pathway and the mesocortical pathway. In the mesolimbic pathway, dopamine neurons are activated in the ventral tegmental area (VTA) of the brain and project to the nucleus accumbens, a part of the brain which is located in an area that is strongly linked to reward processing and motivation called the ventral striatum. While experiencing something rewarding or consuming drugs the dopamine neurons in the VTA get activated and project to the nucleus accumbens in the ventral striatum which leads to a rise of the dopamine levels in this brain area. Since the mesolimbic dopamine pathway is continuously activated during the experience of rewards, it is considered the main brain circuit included in reward processing (Berridge & Kringelbach, 2015; Haber & Knutson, 2010; Klawonn & Malenka, 2018).

Animal studies suggest that social interactions serve as primary rewards (Angermeier, 1960; Evans et al., 1994; Hiura et al., 2018) which implies that these rewards are themselves

pleasurable and motivate organisms without further incentives or rewards. It also leads to significant neuronal and behavioural changes, especially if isolation is experienced during the development (Chen & Baram, 2016). Not only is the drive for affiliation increased if animals experience social isolation, it also triggers the craving for other drugs (Alexander et al., 1978; Lallai et al., 2016; Raz & Berger, 2010; Venniro et al., 2018; Wolffgramm & Heyne, 1991) and elevates the desire for food (Schipper et al., 2018).

In humans, the ventral striatum gets activated by rewarding incentives like stimulant drugs (Leyton, 2007), primary rewards (Wang et al., 2007) like food and sexual behaviour, or secondary rewards like money (Seymour et al., 2007). It is observed that the reward system, the well-being and the hypothalamic-pituitary-adrenal axis interact with each other. Individuals who show sustained activation in the reward brain areas while exposed to positive stimuli, reported greater well-being and had less cortisol output (Heller et al., 2013).

Social rewards can lead to similar responses as other rewarding triggers (Aron et al., 2005; Fliessbach et al., 2007; Rilling et al., 2002), which implies that it motivates humans to seek affiliation. This stays in line with the view that social isolation also leads to a biological reaction to reinstate "social homeostasis" (Matthews & Tye, 2019). Similar to other survival energetic needs like hunger or thirst, social isolation might trigger a chain of physical responses to countermeasure social deprivation (LeDoux, 2012). For example, the reward-related region, ventral striatum, records increased activation in lonely individuals compared to non-lonely people, when seeing pictures of people to whom they have close relationships versus strangers (Inagaki et al., 2016). This result suggests that lonely individuals show a strong desire to affiliate with people they are close to, in order to diminish their unpleasant state. Another reward related structure, the μ-opioid receptor system which influences reward behaviours, pain perception, social reward processing and bonding was connected to a state-dependent model of social motivation in the paper of Loseth et al. (2014). Therefore, a negative motivational state leads to affiliation with safe social contacts for comfort or coping, whereas a positive motivational state elicits social behaviours as for example testing boundaries or mating with new sex partners which exceed comfort seeking and rather serve pleasure or challenge reasons (Loseth et al., 2014).

The research signifies that social interactions are connected to the reward system which guides and motivates individuals. It further interacts with the hormonal system and plays a very important role for the social behaviour of humans.

3. Effects of social isolation

3.1. Effects of social isolation in animal studies

Experimentally designed social isolation studies with humans are still scarce and hard to conduct, but many have been done with animals and showed remarkable results that gave a further indication for human research. If rodents were isolated for a short period, they displayed increased motivation to seek and encounter with other companions (Niesink et al., 1982; Panksepp & Beatty, 1980). If isolated long-term they showed depressive and anxious behaviours (Filipović et al., 2017), and males displayed higher aggression (Karpova et al., 2016; Matsumoto et al., 2005; Mumtaz et al., 2018).

A big domain of animal studies especially focused on the health consequences of social isolation. In fruit flies, it results in a decrease of the lifespan (Ruan & Wu, 2008). In pigs, isolation led to less field activity, an increased basal cortisol concentration and a decreased lymphocyte proliferation reaction to mitogens (Kanitz et al., 2004). Isolated monkeys show a higher inflammatory gene expression and a down-regulated antiviral response (Cole et al., 2015). In experiments with rodents, social isolation led to higher obesity rates and type 2 diabetes (Nonogaki et al., 2007). It further aggravated infarct sizes and oedema in mice and decreased survival after an experimentally induced stroke (Karelina et al., 2009). It led to increased activation of the sympatho-adrenomedullary response, which is activated in stressful situations or through stressing stimuli and showed consequences as immobilization and cold stress in rats (Dronjak et al., 2004). Social isolation also delayed the effects of exercise and it had consequences on building new nerves (neurogenesis) in adult rats (Stranahan et al., 2006).

Social isolation also impacts other behaviours, like drug intake. Animals showed an increased ethanol consumption (Hall, 1998; Lallai et al., 2016; Wolffgramm & Heyne, 1991) and a higher morphine intake (Alexander et al., 1978; Raz & Berger, 2010), when socially isolated. Only sixty minutes of physical social interactions completely diminished the increased tendency of morphine intake of the isolated rats (Raz & Berger, 2010) and the possibility of social contact prevented self-drug administration (Venniro et al., 2018). Social isolation also influences the food intake, resulting in mice and rats consuming more food and producing more adipose tissue mass when isolated (Schipper et al., 2018).

Lastly, social isolation can lead to changes in the brain as shown in a study by Pereda-Pérez et al. (2013). After six and half months of isolation, female rodents displayed deficits in contextual fear memory and had a reduced volume of the hippocampal cornu ammonis 1 (CA1) brain structure. This implies that social isolation triggered the shrinkage of a brain area and the decrease of synaptic levels in parts of the hippocampus. In general animal studies

helped the understanding of the linkage between social isolation and their consequences which may affect humans in a similar way. However, studies focusing on objective isolation in humans are still rare compared to animal research.

3.2. Physical effects of social isolation in humans

Social situation does not only show effects on animals they also have significant consequences on physical and other aspects of humans. Perceived social isolation, as shown in various studies, increases the mortality risk (Alcaraz et al., 2019; Holt-Lunstad et al., 2015; Holt-Lunstad et al., 2010). This effect is shown regardless of gender and skin colour (Alcaraz et al., 2019). It is also associated with lower self-rated physical health (Cornwell & Waite, 2009; Coyle & Dugan, 2012; Miyawaki, 2015) and stronger cognitive impairment (Shankar et al., 2013; Zunzunegui et al., 2003). Loneliness in humans impacts the sympathetic system and is connected with lower inflammatory resilience, with less recovery from sleep, higher blood pressure and less physical ability. In consequence, humans who feel socially isolated have a higher morbidity and mortality risk (J. T. Cacioppo et al., 2011). This stays in line with animal studies mentioned above that examined objective social isolation, even though taking into account that findings in human studies mainly focus on long-term effects.

3.3. Psychological and behavioural effects of social isolation in humans

Social engagements do not exclusively affect physical reactions and drives, they further take influence on the perception and cognition of humans and on psychological and behavioural aspects. Again, the literature focusing on this topic only examines the perceived loneliness, since controlled objective studies with humans on objective social isolation are scarce. Lonely people tend to be more self-centered (J. T. Cacioppo et al., 2017), prefer more space when it comes to interpersonal interaction (Layden et al., 2018) and have a high motivation to avoid social situations that could result in negative social consequences (Gable, 2006). Lonely individuals further focus more on social threats and other negative social stimuli (J. T. Cacioppo & Hawkley, 2009). They also behave less prosocial (Carlson et al., 1988; Williamson & Clark, 1989) even though when the behaviour is perceived by the society, lonely people act opposing, more prosocial (Huang et al., 2016). Counterintuitively, lonely individuals are less motivated to engage in situations with good social outcomes (Gable, 2006). This view stands in contrast to the social motivation theory which assumes an increased motivation to affiliate with others (J. T. Cacioppo & Cacioppo, 2018a; Matthews & Tye, 2019). The social world is experienced more threatening and inflictive by socially isolated individuals, as their brains are hyper-focused on social threats (J. T. Cacioppo & Hawkley, 2009). Researchers

could show that manipulations of loneliness led to more anxious feelings, stronger fear of negative judgement and more coldly acting towards other people (J. T. Cacioppo, 2005). Furthermore, it makes individuals literally feel colder temperatures (Zhong & Leonardelli, 2008) as presumed by the saying, people acting cold towards someone. The negative attitude towards social interactions may trigger precisely the expected social feared interactions and validate the view of lonely individuals. Their impressions of other humans are more negative and behaviours and attitudes less favourable towards them (J. T. Cacioppo, 2005). In consequence, the chance rises that lonely people push others away even though they need and want to affiliate with them to fulfil their social needs (Romero-Canyas & Downey, 2005). This behaviour spiral leads to an infinite loop that can result in more negative views and greater loneliness. The experience of being socially isolated further increases attentional, expectancy and memorial biases that result in a confirmation of their situation. Individuals experience more and more negative social interactions, which can make an impact on the stress regulatory system. A chronic sympathetic stress response to negative social engagements can lead to a cognitive overload, struggle with executive functions and extend to impact the physical health (Hawkley & Cacioppo, 2003). Loneliness is also connected to mental health and is associated with higher depressive symptoms (J. T. Cacioppo et al., 2006), whereas social support influences the general life satisfaction in a positive way (Gow et al., 2007).

In prison studies, significant influences of isolation on the wellbeing of inmates were examined. Beside animal studies, prison studies provide the opportunity to study social isolation more objectively, since it would be classified immoral to isolate humans for a very long period in a different context. Solitary confinement of inmates resulted in severe mental health outcomes, like hallucinations, uncontrolled thought processes, rage (Rhodes, 2004), problems with their concentration, stomach and muscle pain, anxiety, sleeplessness and depression (Gamman, 2001 as cited in Smith, 2006). More than fifty percent of inmates in pre-trial solitary confinement suffered from depression and thirteen percent showed self-mutilating behaviour. Almost all of the subjects showed adverse symptoms as a consequence after four weeks isolation (Gamman, 2001 as cited in Smith, 2006). Forty-three percent of isolated prisoners experienced aversive symptoms after just under forty hours (Stang et al., 2003 as cited in Smith, 2006). In a study by Haney (2003), more precise probabilities underlined the psychological health problems. Ninety-one percent of socially isolated prisoners experienced anxiety and nervousness, seventy percent described their well-being on the edge of a mental breakdown and seventy-seven percent suffered from chronic depression. The majority experienced several of those symptoms at the same time.

3.4. Influences of social isolation on cognitive functions

Social isolation has also an impact on cognitive functions. Previous research validated that loneliness results in a generally worse cognitive performance, less executive cognitive abilities and quicker cognitive degeneration (Gow et al., 2007; Wilson et al., 2007). Objective social isolation has not shown so clear results of social interactions on cognitive functioning, but animal studies focused more on evaluating this connection. Social isolation diminished the learning effect in rats that needed the inhibition of previously learned content like reversal learning or extinction (Schrijver et al., 2004). It further impacted latent learning performance in mice (Ouchi et al., 2013) the latent inhibition in rats (Shao et al., 2013) and memory consolidation (Pereda-Perez et al., 2013). It is stated though that loneliness rather than objective isolation leads to cognitive consequences in humans (Gow et al., 2007; Wilson et al., 2007). This experiment intended to clear up this connection between objective isolation, perceived isolation and cognitive effects.

4. Emotional states

Emotions take a very important role in human life, they help in creating relationships with others, are crucial for communication in social situations and influence the maintenance of health during a disease (Davidson et al., 2003). This importance was not always validated in the research community, as emotions were out of sight in the period of behaviourism, because it was not possible to study them objectively (Skinner, 1976). They were perceived as inferior to the visual behavioural aspects of humans and considered as vague, subjective and not as precise as cognition and reasoning. Newer technologies, however, allow integrating emotions with cognitive neuroscience. This research is recognized as objective and implies that attention, memory and decision making is affected by emotions. Therefore, emotions are impacting cognition and cognition is impacting emotions (Lewis, 2005).

Emotion is a complex construct which is still lacking a single valid and extensive definition. One prominent description defines emotion regarding its characteristics. Therefore, an emotion is an object-orientated, involuntary triggered affective reaction that is associated with temporary changes of the behaviour and experience (Rotermund & Eder, 2011, p. 166). The word originates from the Latin word emovere and means to set something into motion. In this respect, the terms feelings, mood and affect are very important. The subjective perception of emotion is described as a feeling. Whereas affect often refers to the whole topic around emotions and includes feelings, moods and emotions. It is very often also used as a synonym of emotion (Rotermund & Eder, 2011). Mood moreover describes a less extensive state of emo-

tion which lasts over a longer period. Mood incorporates a main interest in this study and comprises a more chronic perception of an emotion (Rotermund & Eder, 2011), which is also described as emotional state in this thesis.

The use of the words emotion, affect, feeling, and mood are often not clearly distinctive and complicate the discourse about this topic. The overall acceptance of all definitions is that emotions comprise a physical reaction and a conscious sensation of a feeling (Iversen et al., 2000; Rotermund & Eder, 2011). The experience of emotion includes physical arousal, feeling, behaviour, cognition and motivation (Rotermund & Eder, 2011). How these elements produce an emotion is differently assumed by researchers (Cannon, 1927; James, 1884; Lazarus, 1982; Schachter & Singer, 1962). For this study, mood, as well as physical and motivational changes of participants, are monitored which are all crucial aspects of emotions and influence each other.

4.1. Characteristics of emotions

Emotions have two different dimensions, first the valence of an emotion and second the arousal. The valence covers the aspect of the positivity and negativity of emotion or mood, whereas the arousal describes the intensity. Positive emotions are experienced pleasant, negative emotions are perceived as unpleasant and either have a high or low intensity (arousal) (Barrett & Russel, 1999).

Emotions serve humans to evaluate the relevance of a stimulus, where to focus the attention, to monitor environmental aspects, to give feedback about progress in coming closer to a set goal and as a general feedback-system that gives information about consequences after actions (Rotermund & Eder, 2011). Stimuli that incorporate emotional value attract the attention of humans more than stimuli without emotional value (Anderson & Shimamura, 2005) and the detachment from emotional stimuli is more difficult (Yiend, 2010). Emotions also influence the memory, probably due to the increased attention focus. Emotional stimuli inherit a higher salience which enhances the persistence of memories (Rotermund & Eder, 2011). Furthermore, they have more distinct characteristics (Edery-Halpern & Nachson, 2004), lead to a higher retrieval from memory (Walker et al., 2009) and have a higher probability to consolidate in the long-term memory (Levine & Edelstein, 2009). The surrounding circumstances of highly emotional loaded memories will fade away even if they are about catastrophic incidents (Talarico & Rubin, 2003), which contradicts the concept of *flashbulb memories* (Brown & Kulik, 1977). Another important factor of emotions is the guidance of behaviour and the influential impact on decisions or judgements (Baumeister et al., 2007). Emotions can be anticipated for a specific incident and direct the behaviour. Aim-directed

emotions give notice of the status quo regarding a set goal, lead the continuing behaviour and have a strong impact on decisions as an intuitive experience of negative or positive feelings. The actual emotional state of a human can also guide the decision of a general judgement in case of uncertain circumstances (Schwarz & Clore, 1983).

However, the most important role of emotions lay in the functions of social interaction. Emotions serve as a regulative mediator in interpersonal situations. They give crucial signals for other social counterparts. A smile can serve as an indication of happiness, of reassurance, or to loosen up a relationship and therefore does not necessarily indicate simply a positive mood (Kraut & Johnston, 1979). Emotions can hold a lot of different meanings and are crucial during social interactions. They give guidance in stimulating environments, direct the attention and set importance to different inputs.

4.2. Neurological processes underlying mood states

As with most psychological topics, neurological processes play an important part to get a broader understanding of the subject. This is why a short overview of neurological contents around emotions and moods are presented in this paragraph. Emotions are thought to be processed in specific brain areas. The first proof to underline this view came after lesions studies on the temporal lobe and the amygdala resulted in altered emotional responses (Klüver & Bucy, 1997). After many researchers focused on the exploration of emotional brain areas, one very prominent neuronal model was proposed: the limbic system, it is associated with the experience of emotions and feelings. This system tries to convey all brain areas that are included in the processing of emotions (Papez, 1995). The original brain structures that were considered to be part of the limbic system are the hypothalamus, the amygdala, the thalamus, the septal area and the hippocampus even though there is no coherent consensus. These brain structures are considered evolutionarily evolved and behave automatically (Pessoa, 2008).

Newer research connects more and different brain areas to affective experiences. The core and extended regions include the amygdala, the nucleus accumbens, the hypothalamus, the anterior cingulate cortex, the orbitofrontal cortex, the ventromedial prefrontal cortex, the brain stem, the ventral tegmental area, the hippocampus, the septum, the periaqueductal grey, the basal forebrain, the anterior insula, the prefrontal cortex, the anterior temporal lobe, the posterior cingulate cortex, superior temporal sulcus and the somatosensory cortex (Pessoa, 2008). This extensive list shows the complexity of emotional processing and that a great variety of brain areas can be involved. Many scientists also distance themselves from the idea of a certain emotional brain system since many parts like the hippocampus are not necessarily linked to affective aspects and other areas as mentioned above are now associated with emo-

tional experiences. The brain systems included in emotional processing are fluctuating with the scientific progress and the idea of a limbic system might need to get renewed. As proposed by more recent literature emotion and cognition should not be seen as separate entities but rather as connected (Gray et al., 2002), which reduces the probability of a single affective system that is exclusively associated with emotions.

4.3. Impact of social factors on mood states in humans

Emotions have a variety of effects on humans and play an important role in their daily life. They give specific situations meaning, enrich experiences, motivate behaviours, alter memory, incorporate motivative value and play a crucial part in the development of mental disorders as described in the previous paragraphs. Therefore, circumstances that impact the affective states can have significant consequences for humans and social aspects are one of them.

Perceived social isolation can influence emotions, it can trigger mood disorders like anxiety and depression, resulting in difficulties with attention, poor performances and lack of motivation (J. T. Cacioppo & Patrick, 2008). In many other studies, the relation of social interaction with mood could be validated. A positive mood leads to greater interest in social interactions and an increased quantity and quality of conversation compared to a negative mood (Cunningham, 1988a; 1988b). Positive emotions are also connected to higher participation in social events (Clark & Watson, 1988). The other way around is also true, social interactions trigger positive emotions compared to a neutral situation without social contact (McIntyre et al., 1991; McIntyre et al., 1990). Further studies underline the finding that positive emotions are higher when individuals engage socially (Watson et al., 1992).

Opposed to that, social circumstances can also induce negative emotions. As shown in a study, arguments and confrontations (Clark & Watson, 1988; Vittengl & Holt, 1998) as well as interactions with low communicative qualities (Vittengl & Holt, 1998) elicited negative mood effects. Social rejection also leads to the experience of negative feelings like pain as mentioned before (Eisenberger et al., 2003). Even though social rejection does not equal social isolation, as it implies an aversive act by other social beings (Eisenberger, 2012), it might be a predictor of social isolation.

Another finding concerns the different weighed impacts of social experience on positive and negative emotions. Positive social interactions increase the daily positive mood but do not impact the negative mood (Rook, 2001). Whereas negative social encounters show relations to positive and negative mood (decrease the positive and increase negative mood) (Rook, 2001). Another study could find an impact of positive and negative social interactions

on positive and negative emotions (Newsom et al., 2003), which contradicts the former study. In a longitudinal design, the influence of negative interactions on negative emotions was more intense than the impact of positive interactions on positive effects (Newsom et al., 2003), which underlines both study results mentioned before. Negative social interactions seem to have a stronger impact than positive emotions on both valences of emotions. Nevertheless, both social experiences play a significant role in the mood perception of humans. Moreover, being integrated in social groups led to a reduced risk to experience depression and when suffering from it could minimize it by almost twenty-five percent after joining social groups as sports clubs, hobby groups and others (Cruwys et al., 2013).

Again, just a few human studies explore the connection between social isolation and mood with the exception of solitary confinement studies. As described in recent chapters, solitary confinement led to anxiety and depression (Gamman, 2001 as cited in Smith, 2006; Haney, 2003), which indicates a very strong impact of social isolation on mood states. Even in an animal study with prairie volves, social isolation could be linked to anxiety and depressed related behaviours (Grippo et al., 2007).

All these studies imply that social encounters, interactions and conversation have a strong influence on the mood of humans. Socially isolated individuals do not have positive social engagements with others. Therefore, they are less likely to gain positive emotions because of the lack of social interactions and, according to solitary confinement prison studies, these individuals develop a lot more negative feelings (Gamman, 2001 as cited in Smith, 2006; Haney, 2003).

5. Stress

Stress is a very prominent word in the daily lives of humans, but it comprises a broad topic and a lot of different aspects. Stressors have various consequences for humans, including a suppressed immune system and reduced inflammatory reactions caused by an increased activation of the sympathetic system. Especially, a longer exposure to a stressor leads to increased cortisol levels, which in turn decreases the activity of the immune system (Huppelsberg et al., 2009). In addition, stress particularly impacts the health. It influences the glycogenesis which interacts with the sugar levels in the blood and reduces insulin responsiveness. This elevates the risk of diabetes type 2. An increase of lipolysis, which induces higher fatty acid levels in the organism, can also be monitored as results to stressful stimuli (Huppelsberg et al., 2009), which often result in weight gain (Klinke et al., 2010). Corticoids moreover cause a protein degeneration, leading to a reduction of the bone density that can trigger osteo-

porosis and influences the water circulation and electrolytes. The increased blood pressure can be followed by coronal disorders and heart insufficiency (Aktories et al., 2017; Huppelsberg et al., 2009). Other physical responses to stress include an increased sensitivity to sensory stimuli (acoustic, tactile, gustatory, olfactory), impacts on emotional states (euphoric or depressive symptoms), a higher probability to experience cramps, an acceleration of aging and influences on the mineral balances (Aktories et al., 2017; Huppelsberg et al., 2009).

The responses of cortisol, one major hormone released during the experience of stress comprise the second major interest within this study. Besides the health effects cortisol interferes with neurological communication. It changes the sensitivity to neurotransmitters, inhibiting the hyperpolarization of serotonin neurons in rats. In consequence the serotonin receptors get less responsive after a stressful stimulus (Joëls et al., 1991). Cortisol generally changes the dominance of neuronal processes as also shown in human studies (Dias-Ferreira et al., 2009; Schwabe & Wolf, 2013).

Again, no single definition for the concept of stress exists in the literature. A very comprehensive definition includes the three aspects: excitability/arousal, perceived aversiveness and uncontrollability. According to this definition, stress develops as a result of three components; high arousal (physical), an aversive experienced situation and uncontrollability to deal with this situation (Kim & Diamond, 2002). Having control over a situation has a key role in the perception of stress. This also accounts for differences in stress levels between individuals which may perceive circumstances more predictable and controllable than others. Stress develops if a situation or incident is experienced as threatening, challenging or harmful. This is described as the primary appraisal. The secondary appraisal refers to stress that occurs if external or internal requirements are perceived to exceed resources (Lazarus & Folkman, 1999). This definition complies with the modern transactional stress concept which states that stress appears in an interaction between an individual and their environment (Folkman & Moskowitz, 2004; Kim & Diamond, 2002; Lazarus & Folkman, 1999). In comparison to the stimulus-oriented stress concept, in which stress elicits as a consequence to a specific stimulus or life event (Dohrenwend & Dohrenwend, 1974), or the reaction-oriented stress concept which mainly focuses on the adaptive processes to stress within a human (Cannon, 1929; Selye, 1976). The later concepts fail to explain the different reactions to the same stressor of different people. Stress needs to be seen in the context between a person and the environment. It requests an individual to cope with the demands with their given resources, which vary in each situation.

The experience of stress has its necessary value, it follows the U-shaped principle that

increases performance if moderately experienced. Too much or little stress on the other hand decreases the performance success (Duffy, 1957; Yerkes & Dodson, 1908). An extreme under- or overstimulation is experienced as unpleasant, whereas mediocre stress levels are motivating for individuals. Different tasks also require different demands of arousal which define the relationship between the optimum performance and the physical arousal (Selye, 1976).

Stress can be divided into different levels, it can influence cognitive-emotional elements, behavioural levels or physiological aspects of an individual. Further, they can be distinct regarding the duration of a stress response (short-, middle-, or long term). Lastly, the dimension of micro- versus macro stress, chronic or acute stress and universal versus personal stress can be classified (Bodenmann & Gmelch, 2009). The division of stress in so many aspects shows the complexity of the concept and the involvement many different elements.

5.1. Physical processes during stress

With the physical aspects of stress, scientists refer to the processes happening in the body which are governed by the endocrine system. This system is responsible for the release of hormones into the bloodstream where they diffuse to specific organs (Huppelsberg et al., 2009). During a stressful situation, catecholamines (adrenalin and noradrenalin) and the hormone cortisol are released. More precisely, two systems are involved in the control of the stress response, the sympatho-adrenal medullary axis of the autonomic nervous system (ANS) which is responsible for the distribution of the catecholamines and the hypothalamus-pituitary-adrenal axis (HPA-Axis) which governs the release of cortisol. The ANS-axis is responsible for the immediate physical stress response and activation of the sympathetic system, whereas the HPA-axis has longer-lasting effects. These processes are a natural reaction of the body to resume to the homeostatic value after a stressing stimulus (Ulrich-Lai & Herman, 2009). Stressors are triggering specific stress responses of the autonomic nervous system which are described as fight-flight reactions by Walter Cannon (1932). He was one of the first who focused on the homeostasis and the homeostatic response in an organism to threat and danger in animals. The cardiovascular response to dreadful situations leads to an activation of the sympathetic nervous system and in consequence to an increase of heart rate, blood pressure, breathing and vascular constriction (constriction of blood vessels) everywhere except within voluntary muscles. Changes of the heart rate can in addition influence the mood and endocrine processes (Lovallo et al., 1990). These adaptive responses in the body have a purpose: to enhance the oxygen sustenance in the body, to release glucose from the liver and to ensure blood circulation in the brain and muscles. Further adaptations include a down-regulated digestive system, increased memory and wider pupils (Ulrich-Lai & Herman, 2009).

These responses are mainly governed by the released catecholamines from the sympatho-adrenal medullary axis. The physical changes caused by an encounter to a stressor, serve to focus energy in certain body areas and to increase attention to threatening circumstances.

The second crucial stress reaction proceeds over the hypothalamus-pituitary-adrenal axis (HNA-Axis). Within this axis, firstly, the cortical-releasing-hormone (CRH) is triggered, it is a precursor to the release of the adrenocorticotropic hormone (ACTH) from the pituitary. After ACTH is distributed in the blood circulation, it triggers the release of cortisol from the adrenal cortex. To regulate the stress response, the hormones, CRH, ACTH and cortisol induce negative feedback loops. If the end product cortisol spreads through the body, the production of CRH and ACTH gets reduced (Aktories et al., 2017; Huppelsberg et al., 2009; Klinke et al., 2010). The CRH also affects the release of hormones of the limbic system: serotonin, noradrenalin, acetylcholine and vasopressin (Netter & Hennig, 2002). Through the negative feedback loop, the regulation of the hormonal distribution process and the finalization of the stress response are ensured. The habituation ability of humans plays a very crucial role especially for developing maladaptive health consequences. Individuals who are unable to habituate to stressful events experience an allostatic load (Fink, 2016; McEwen, 1993), with an increased morbidity risk as result. A deviant feedback response to stress can cause depression, anxiety, cancer, and neurodermatitis. More precisely an overreaction of the HPA-axis is associated with cancer, anxiety and depression, diabetes mellitus, adiposity, panic disorders, alcoholism, hormone disorders (cushing syndrome), anorexia and a hyper reaction of the thyroid glands, whereas an under-reaction of the HPA-axis can result in auto-immune diseases, neurodermatitis, arthritis, asthma, multiple sclerosis, fatigue, pain disorders, diabetes type-1, sub-function of thyroid glands and chronic inflammations (Stratakis & Chrousos, 1995). Dysfunctions of the HPA-axis can be acquired through chronic stress or traumatic experiences or be caused by a genetic predisposition (Knoll et al., 2017).

Even though a maladaptive stress response might result in negative health outcomes cortisol is a hormone necessary for living and responsible for the longer-lasting effects to a stressor. Cortisol levels are connected to the circadian rhythm and guide many physical aspects of the body in everyday life. For example, the cortisol level is higher straight after a person wakes up, which is classified as the cortisol-awakening-response (CAR) (Clow et al., 2010). The morning awakening response is a natural process of the body. Before waking up, the adrenal gland has a reduced sensitivity to the increased ACTH, which is controlled by the suprachiasmatic nucleus (SCN) that is mediating the circadian rhythm. Further, a contribution of the hippocampus is considered in the CAR. Three main processes are happening during the

wakening: activation of the HPA-axis, reduced sensitivity to ACTH of the adrenal gland before waking up and increased sensitivity to ACTH after waking up, which is guided by the SCN- extra-pituitary pathway (Clow et al., 2010). To assess the cortisol awakening response, the cortisol level around thirty minutes after waking up is deducted by the cortisol level straight after waking up. The increase between the two levels represents the cortisol awakening response (Elder et al., 2014).

The circadian rhythm also shows an increased cortisol release in general between three am and ten am and decreases afterwards rapidly. The lowest cortisol level is between midnight and three am. Closely linked to the circadian rhythm are other parts of the feedback loop system, the highest sensitivity to cortisol occurs during the time of the lowest levels of cortisol. In general, the daily cortisol release is between 12-30 milligram (30-80 μmol) in the blood and the level can vary from 5 to 25 μg/100 ml (138-690 nmol/L) in a healthy person (Aktories et al., 2017). Since cortisol is also released after the experience of an acute stressor, it can intervene with the circadian rhythm of people.

Cortisol can be measured through blood but also in a non-invasive manner through saliva or urine. A stress response after repetition to the same stress exposition is reduced in general. Scientists refer to this phenomenon as habituation to a specific stressor (Knoll et al., 2017). The majority of participants who needed to perform a five-minute speech in front of an audience show a reduced stress response after repeated trials as shown in a study. The only difference apparent, between individuals who can habituate in a stressful situation and individuals who cannot, are their personality traits. The participants who cannot habituate to a stressor describe themselves less extraverted, more emotionally insatiable, and less confident (Kirschbaum, Prüssner, et al., 1995).

Stress comprises a very important physiological process guiding various other aspects in the body and inheriting important value in certain situations. The physical processes are thought to be happening to redirect energy to other more important sources like the prevention of apoptosis or to prohibit autoimmune reactions and diseases. Physiological stress responses lead to less inflammation as a positive consequence and are used as a therapy for allergies and autoimmune diseases in clinical settings (Klinke et al., 2010). An acute stressor leads to an adaptive response that increases successful coping, but chronic stress can become dysfunctional and increase the morbidity risk or psychological disorders (Ulrich-Lai & Herman, 2009).

5.2. Psychological stress

One can distinguish between physiological and psychological stressors. Psychological stress is induced by non-metabolically claiming tasks. This excludes physical stressors like extreme sportive activity, biological challenges like caffeine and physical-psychological stressors like the cold pressor test which triggers stress with cold water (Dickerson & Kemeny, 2004). Psychological stressors are stimuli that do not predict physical harm or threats. Psychological stress became a major part of stress experienced in the modern world since many people suffer from chronic stress without a metabolically demanding task.

A meta-analysis could show that psychological stressors are also connected to the HPA-axis and in consequence can lead to cortisol release. The two main psychological stressors in the study were uncontrollability and a social-evaluative threat that implies a possible negative judgment of others (Dickerson & Kemeny, 2004). These stressors are threats to the social self like status, acceptance or self-esteem (Gilbert, 1997) and result in coping mechanisms of the body (Dickerson et al., 2009). Individuals try to maintain their social self (social self-preservation-theory) (Dickerson et al., 2004).

Social stressors not only impact the physical stress response, they can also increase anxiety in humans (Dickerson & Kemeny, 2004). Further uncontrollability affects the endocrine stress response under certain circumstances. Uncontrollability refers to the inability of individuals to influence the outcome with their actions and creates a situation of inevitable failure (Averill, 1973; Levine & Ursin, 1991; Thompson, 1981). The connection of psychological stress and the HPA-Axis in human research is not that clear. Uncontrollability only affects people if a very important aim of this person is threatened. In connection with a threat to the social self, the strongest cortisol release is elicited. The effect size almost increased three times if social-evaluative threats and uncontrollability were connected in a stressful task (Dickerson & Kemeny, 2004). This research exhibits the importance of non-physical hazards for the experience of stress and highlights the individual aspects included in physical processes. In another meta-analysis, the neuronal substrates involved in physiological and psychological stress were examined (Kogler et al., 2015). The only shared brain areas in both stressors were the anterior insula (AI) and inferior frontal gyrus (IFG). Physiological stress is connected to the affect processing brain parts and cognitive areas like the striatum, the middle cingulate cortex or the insula. On the other hand, psychological stress showed activations in the right superior temporal gyrus and deactivation of the striatum. The striatum especially shows distinct reactions to both stressors. The ventral striatum is deactivated during psychological stress, whereas the dorsal striatum is activated during physiological stress. The dorsal striatum

is associated with motoric processes and the ventral striatum with reward experiences. This underlines the different consequences to a specific stressor. Therefore, the physiological stress reaction with the activation of the dorsal striatum is connected to the fight-flight response and the psychological stress process directed towards emotion regulation, goal-directed behaviour and a decreased reward processing. Even though psychological and physiological stress responses share a lot of aspects, they have distinct values and need to be perceived distinctive (Kogler et al., 2015). Social isolation can be considered a psychological stressor since it is not a physical demanding task. It can also include values of uncontrollability if a person is not able to influence its social interactions.

5.3. Effects of social isolation on stress responses in animal studies

In various animal studies, a specific effect of social isolation on the stress response could be examined. Social isolation led to increased catecholamine output and oxidative stress in the aortic arch in rabbits (Nation et al., 2008). It also showed direct effects on the cortisol balances as pigs had higher cortisol levels as consequence (Kanitz et al., 2004). Social isolation also impacted genes of piglets that regulate the glucocorticoid response in the frontal cortex (Poletto et al., 2006).

Another study, assessed the connection of relative stress responses to different qualities of stressors. Marmosets were isolated for either eleven hours in a small cage which assembled a milder stressor or for eleven hours in a small cage with a caption procedure with a net beforehand followed by a holding period for five minutes, which assembled a more severe stressor. The two conditions led to a different cortisol release, the primates that were only isolated in a small cage had an increased cortisol output in the afternoon, whereas the marmosets who experienced eleven hours of isolation and restraint handling prior showed an elevated cortisol level in the morning and afternoon (Smith & French, 1997). This displays that variation of the intensity of a social stressor can impact the hormonal stress response.

Moreover, female monkeys have lower cortisol levels and are able to cope better with stressful situations when they are well-integrated in a social group (Crockford et al., 2008; Wittig et al., 2016). Whereas a loss of a strong social bond within monkeys led to higher cortisol release indicating a physical reaction which might serve to reinstate the social network (Engh et al., 2006). Animals studies state a strong link between social isolation and cortisol stress responses showing the importance of social interactions for endocrine processes.

5.4. Effects of social isolation on stress responses in human studies

Not only do animal studies give proof for the association between social isolation and the physical stress response, human research also underlines that connection. An important factor that influences the biological circuits caused by a stressor is the perceived social support (Uchino et al., 1996; Uchino & Garvey, 1997). Individuals who have higher social resources have different physical reactions. Social support can lessen stress because it reduces perceived negative emotions connected with stress due to increased support (Uchino et al., 1996; Uchino & Garvey, 1997).

As in other parts of this thesis, most of the studies examine the associations between loneliness and its effects but it is assumed that objective social isolation might has similar impacts on the physical stress response. The HPA-Axis shows increased activation in lonely individuals (Adam et al., 2006; J. T. Cacioppo et al., 2000; Steptoe et al., 2004) and chronically lonely individuals can develop a glucocorticoid resistance (J. T. Cacioppo & Hawkley, 2009). Perceived social isolation also led to a changed expression of genes regulating the cortisol levels. Resulting in an under-expression of anti-inflammatory glucocorticoid genes and an increased expression of genes bearing elements for promoting inflammatory reactions (Cole et al., 2007). Subjectively isolated older individuals suffered from suppressed lymphocytes and monocytes in direct proportion to the cortisol levels in the bloodstream and their leucocyte sensitivity to glucocorticoids were diminished (Cole, 2008).

Loneliness also predicts an increased morning cortisol release in individuals. The feeling of loneliness throughout a day elevated the cortisol awakening response the next morning and influenced the daily cortisol rhythm (Adam et al., 2006; Doane & Adam, 2010). Objective social isolation measured with a questionnaire was also associated with an increased daily cortisol release and cortisol awakening response in men and women (Grant et al., 2009). These studies reveal the connection of subjective or objective isolation and its effects on the cortisol rhythm within humans. A dysregulated cortisol release can increase the risk for mental disorders as substance abuse, major depression or post-dramatic stress disorder (Chrousos, 2009) indicating also a strong effect on affective aspects in humans.

6. Research gaps in the state of the art

The topic of social isolation embraces many unpleasant circumstances for people. That is why it lacks extensive research, since it is not qualifying for the high ethical standards of human research. In consequence, as very often in social science, the majority of studies are done with animals as they require less ethical standards and offer easier sampling (Ghasemi &

Dehpour, 2009). But animal studies are unable to examine unique human entities like mood or complex thought processes and the transfer of the results on humans need to be done carefully.

So far, most research of social isolation with humans has been done only on long-term effects in uncontrolled manners. The majority of the studies done with people include self-indicated values of perceived loneliness or chronic social isolation (Adam et al., 2006; J. T. Cacioppo et al., 2000; J. T. Cacioppo & Cacioppo, 2018a; 2018b; J. T. Cacioppo et al., 2017; J. T. Cacioppo & Hawkley, 2009; J. T. Cacioppo et al., 2011; J. T. Cacioppo et al., 2006; J. T. Cacioppo & Patrick, 2008; Carlson et al., 1988; Cole et al., 2007; Cole, 2008; Doane & Adam, 2010; Gow et al., 2007; Huang et al., 2016; Inagaki et al., 2016; Kross et al., 2011; Romero-Canyas & Downey, 2005; Shankar et al., 2013; Steptoe et al., 2004; Williamson & Clark, 1989; Wilson et al., 2007; Zhong & Leonardelli, 2008; Zunzunegui et al., 2003). Some studies focus on social support (Gow et al., 2007; Uchino et al., 1996; Uchino & Garvey, 1997) or assess objective social isolation in a questionnaire as a more valid measurement (Grant et al., 2009), but these values also rely on self-stated data and are not acquired in a controlled experimental matter. Lastly some studies focus on the social network (Bzdok & Robin, 2020; Cruwys et al., 2013; Pinquart & Duberstein, 2010; Reblin & Uchino, 2008; Smith & Christakis, 2008) but this approach can just be indirectly referred to social isolation and also focuses on longer lasting effects of social interactions. As a consequence, the effects of studies regarding social isolation with humans show a great variety and leave many questions open.

Scarcely any research focused on the short-term consequences of social isolation. Mostly loneliness values, the social network or self-stated answers are used as an indicator of objective social isolation, but both measurement approaches imply a longer period of social deprivation.

One of the few studies involving humans regarding social isolation are prison studies with inmates in solitary confinement (Haney, 2003; Gamman, 2001 as cited in Smith, 2006; Rhodes, 2004; Stang et al., 2003 as cited in Smith). These studies are more valid to measure social isolation in an objective manner, but also focus on longer periods of social isolation.

A recent study focused on a similar topic as addressed in this thesis while examining the short-term effects of social isolation on reward circuits in the brain within a controlled setting. It was visible in neuronal images that distinct cortical regions are active eliciting the motivation to look for social contact after a ten-hour isolation period (Tomova et al., 2020). Nevertheless, rarely studies specialised in the short-term effects of social isolation on specific

human entities as mood or stress responses in an experimental setting to this point, hence this experiment is dedicated to clarify this niche. Emotional states and stress are shown to be influenced by social isolation and comprise very important factors for the well-being of humans, therefore this study aims to give further insight to the connection of short-term social isolation with these very crucial aspects.

7. Research questions and hypothesis

Referring from the presented literature, emotions are strongly influenced by social interactions (Rook, 2001; Newsom et al., 2003) in a positive (Clark & Watson, 1988; Cruwys et al., 2013; McIntyre et al., 1991; McIntyre et al., 1990) and negative way (Clark & Watson, 1988; Eisenberger et al., 2003; Vittengl & Holt, 1998). Further social rejection results in similar responses like pain experiences (Eisenberger, 2015) and brain areas connected to pain and emotion are also activated during isolation (Kross et al., 2011). Solitary confinement prison studies especially lead to the inference that social isolation can impact the mood severely and can cause anxiety and depression (Gamman, 2001 as cited in Smith, 2006; Haney, 2003). Taking this into account the first main hypothesis states a higher increase in negative mood during the isolation condition compared to the neutral condition (H1).

Social isolation not only influences the mood of individuals, it further increases the stress response as shown in animal studies (Engh et al., 2006; Kanitz et al., 2004; Nation et al., 2008; Smith & French, 1997). Perceived isolation additionally impacts the cortisol levels in humans (Adam et al., 2006; J. T. Cacioppo et al., 2000; Doane & Adam, 2010; Grant et al., 2009; Steptoe et al., 2004) and leads to an increased cortisol awakening response (Adam et al., 2006; Doane & Adam, 2010; Grant et al., 2009). In conclusion, the second main hypothesis and sub hypothesis are formed, which state that a higher stress response is expected during the isolation condition (H2) and an increased cortisol awakening response after the isolation condition (H2.1).

Assuming a connection between social isolation and stress leads to the inference of increased heart rates during social isolation, as an accelerated heartbeat is a consequence of the immediate sympathetic stress response (ANS) (Ulrich-Lai & Herman, 2009). Higher frequencies are correlated to the activation of the sympathetic nervous system and lower frequencies to the parasympathetic activation (Shaffer & Ginsberg, 2017). Concluding from this, an increased heart rate is assumed throughout the isolation condition in comparison to the neutral condition (H3).

Furthermore, humans have evolved as a social species (Dunbar & Shultz, 2007) and show affiliation behaviour to enhance survival benefits (J. T. Cacioppo & Cacioppo, 2018a; J. T. Cacioppo & Patrick, 2008). Social isolation motivates individuals to engage with others as their reward system is activated during social interactions (Aron et al., 2005; Fliessbach et al., 2007; Inagaki et al., 2016; Rilling et al., 2002) and when socially deprived humans try to reinstate social homoeostasis (Matthews & Tye, 2019). Concluding from this, it is expected that the social isolation condition will lead to a higher need for social contact compared to the neutral condition (H4).

Perceived social isolation lastly shows impairments in cognitive performance and cognitive abilities (Wilson et al., 2007). Furthermore, coping with stress and emotional regulation can result in energy usage which leads to less cognitive resources to self-regulate (Evans et al., 2016). In various animal studies, effects on learning (Ouchi et al., 2013), inhibition tasks (Shao et al., 2013) and memory (Pereda-Perez et al., 2013) were apparent thus it is also expected that the experimentally induced state of social isolation leads to less cognitive ability (motor speed, inhibition control and working memory) than the neutral condition (H5). Cognitive processes are playing a key role in the experience of emotions and stress responses. Knowing if cognitive abilities are influenced by social isolation might give further explanation of changing emotions and hormonal cortisol levels as effect to social isolation. Reduced cognitive and motor abilities might mediate the influence of social isolation on emotions and physical stress responses.

Based on the presented literature and the addressed aims of the study, the overview of the research questions and hypotheses are the following:

1. Does an experimentally induced state of social isolation (lasting for eight hours) lead to an increase in negative mood over time, and in comparison, to the neutral state?

2. Does the experimentally induced social isolation (lasting for eight hours) lead to an increase in physiological stress response (cortisol) over time, and in comparison, to the neutral state?

7.1. Main hypothesis

Hypothesis 1: The experimentally induced state of social isolation leads to more negative mood over time than in the neutral condition.

Hypothesis 2: The experimentally induced state of social isolation leads to a higher stress response over time than the neutral condition.

Hypothesis 2.1: The experimentally induced state of social isolation leads to a higher cortisol awakening response the next morning than after the neutral session.

7.2. Sub-hypothesis

Hypothesis 3: The social isolation condition will lead to higher physical arousal (heart rate) than the neutral condition.

Hypothesis 4: The social isolation condition will lead to a higher need for social contact than the neutral condition.

Hypothesis 5: The experimentally induced state of social isolation leads to less cognitive ability (motor speed, inhibition control and working memory) than the neutral condition.

8. Methods

8.1. Subjects

For the study, the examination of 30 healthy females was planned. The power analysis with a medium effect size (Cohen's f of 0.25), the Alpha level .05 and a power of .08 resulted in 28 participants. To account for an expected 10% drop-out as a result of unusable data, 30 subjects were supposed to be tested. Due to time reasons, only 24 participants were included in the calculation of the questionnaire data, the heart rate and the cognitive tasks (motor speed, inhibition control, working memory). In the cortisol data, only sixteen participants were included since the biochemical analysis required more time. The special circumstances resulting from the COVID-19 pandemic delayed the testing procedure, which enforced an analysis on a reduced sample size.

Only females with hormonal contraception were tested in the experiment in order to minimize variation of the hormonal cycle (Kudielka et al., 2009) and to have a higher comparability. Therefore, only women with hormonal contraception were included. Men show a different hormonal balance and for this explorative study, the capacity was not given to include male participants, since a larger study sample would have been needed to give inferences about both genders. In addition, the participants were required to be non-smokers with low scores of loneliness (Russell, 1996).

The participants received €195 as a reimbursement if they completed the whole study. The payment was structured as follows: for each completed session the participants obtained €60, so €180 in total for the three experiment days. Additionally, they received €5 if they did the morning testing which consisted of two questionnaires and two saliva samples after a completed session. All participants were informed about the reimbursement procedure and signed an informed consent beforehand.

In summary, the first 24 participants provided the data for the questionnaire values, the heart rate and the cognitive tasks (motor speed, inhibition control, working memory) and the first 16 participants the data for the cortisol analysis.

The average age of the first 24 participants is 22,2 years. Twenty-two of the subjects speak German as their mother tongue and the other two participants have a C1 Level in German. All women are right-handed and the average of their menstruation length is 4,6 days (with two missing values). Two participants used the Nuva-Ring as hormonal contraception, three the hormonal spiral, two an implanon and the rest 17 women used a hormonal pill. The preselection questionnaire ensured all defined including criteria seen below.

8.2. Including criteria

- Females who take hormonal contraceptives
- Age: ≥18 ≤ 35 years
- Heterosexuality
- Normal body mass index (BMI) ≥18 ≤ 25
- German mother tongue/ C1
- Healthy (no history of neurological or psychiatric diseases, no past or current alcohol/ drug abuse)
- Non-smokers
- Low scores on loneliness scale - (assessed by the UCLA Loneliness Scale)
- Well socially integrated (measured by the size of social network)
- Low scores on internet addictive behaviour
- Low scores on irregular food behaviour (assessed by the Eating Disorder Examination Questionnaire (EDE-Q))
- No pregnancy

8.3. Experiment

The whole study consisted of three phases: a preselection online questionnaire, the experimental sessions and a morning procedure, the morning following a testing day. The preselection online questionnaire gathered information about demographic aspects, the handedness, the body mass index and the menstrual cycle. It screened in addition for psychological aspects of eating behaviour, loneliness, drug intake and phone/internet addiction. With this procedure, clinical salient individuals could be filtered and all inclusion criteria were ensured. The study was approved by the Ethics Committee of University of Vienna.

8.3.1. Experimental study

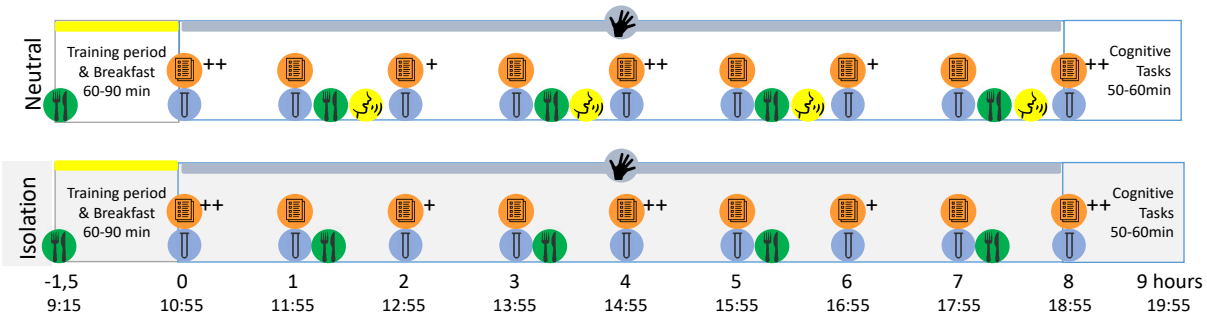
The participants included in the analysis were tested from 22nd of November 2020 to 19th of October 2020. The thesis is incorporated in a larger study which compares three different conditions and were differentiated as follow:

1. Social isolation condition: Includes no social contact for eight hours and food every two hours
2. Hunger deprivation condition: Includes no food for nearly ten hours and social contact every two hours (Not included in the present thesis)
3. Neutral condition: Includes food every two hours and social contact every two hours

Each participant undertook each session. The order of the conditions was counterbalanced between the participants. In total six different orders existed and were given to a set of five participants by random choice. In the social isolation condition, participants did not have any contact with humans. This implies no talking, hearing, texting or seeing of other people after the experimental isolation began. The subjects were provided with food every two hours within this session. In the neutral condition, the participants had social contact over the phone or laptop and were provided with food every second hour. This thesis only focuses on the social isolation condition in comparison to the neutral one (Figure 1).

Figure 1

Timeline comparing both conditions (Neutral = top; Social Isolation = bottom)



Note. Green circle = meals. Orange circle = questionnaires. No plus () shortest version, one plus (+) middle version and two plus (++) longest version of the questionnaire. Blue circle = saliva samples. Gray circle = activities. Yellow circle = manipulative variable of social interactions with family or friends via call. 9:15 – 19:55 = time.

The duration of each session lasted around 10.5 hours. It began, depending on whether it was the first testing date, between 9:15 am to 9:45 am and ended approximately at 8:15 pm. The experiment started with a breakfast followed by an introduction phase, which again depending on if it was the first session and on the condition, lasted from 30 to 90 minutes. In this phase, the subjects signed the informed consent, were presented with the space they were allowed to use, got accustomed to the experimental procedures, practised the use of vials for saliva samples, practised to fill in the questionnaires on the iPod, got accustomed to the food procedure and the conversations on the phone or laptop and had a test trial of the cognitive tasks for the end of the session. After that, the participants had a short variable relaxing time, in which unresolved questions could be asked. The testing time began with the first measurement point at 10:55 am and ended after the subjects fulfilled some computer-based motor control and cognitive control tasks, at 7:50 pm. Each hour during the testing time the participants needed to fill in questions on the iPod and give a saliva sample. The iPod rang to announce each measurement point, so none could be missed. It also notified for the meals and conversation slots. Through this approach, no personal contact of the experimenter was needed. During the testing period the meals were served at 11:55 am, 1:55 pm, 3:55 pm and 5:55 pm in the social isolation and neutral condition. The food was placed on a little desk in front of the test room before the mealtime and the participants collected it independently. Therefore, human contact could be completely avoided. In the neutral condition, the meals were followed by a 30 minutes conversation time with friends or family members. After the testing period in the experiment room at 7:50 pm, the participant went to a room next door and fulfilled an ap-

proach-avoidance task, a motor speed task, an inhibitory reaction time task and a working memory task on a computer for around 50 minutes. In this thesis only the three later tasks are included. The testing period ended with a follow-up questionnaire examining personal opinions regarding the study. After this period the experimenters entered the room and offered the participants cookies for successful completion of the test day and an explanation of the morning procedure was given. The morning procedure consisted of two saliva samples and two questionnaires. All participants were asked to give a saliva sample and fulfil a questionnaire straight after waking up and 30 minutes later. The room was equipped with a camera, so that the experimenter could ensure the participant's well-being and if the experiment was running as planned.

Figure 2

Table in experiment room before session

Note. Table containing from right top = saliva cooling box, iPod for questionnaires and notifications, tissues, water spray for HR belt, HR belt, vessel filled with tap water. At the bottom left an overview of the isolation session, a manual with explanations and at the bottom middle, breakfast.

A short pilot study was conducted with eight trial participants to train the experimental procedure and ensure a smooth execution. So, in case of difficulties arising throughout the trial session, adaptations for the real experiment would have been possible. One individual was tested for the control condition and two participants were tested for the isolation and the food deprivation condition. After the pilot study, a smooth procedure was guaranteed and only small amendments were conducted.

8.3.2. Recruitment

The recruitment of the study was conducted through flyers in public spaces and an electronic university recruiting platform (https://labs-univie.sona-systems.com). Interested participants contacted the research team and received an E-Mail about the study, with an informed consent sheet, and a link and code to the SoSci survey questionnaire.

After ensuring the inclusion criteria through the preselection procedure the individuals were called and three fitting testing dates were scheduled while taking the menstruation cycle into account. The participants were also briefly informed about the study and the preparation they needed to complete before the testing dates. Straight after the call, if three testing dates were found, the subjects received an E-Mail with detailed information about the preparation. Depending on which session was randomly assigned to the participants as first condition, a conversation slot table and activity sheet was attached to the Mail. In the hunger deprivation and neutral condition both files were needed prior to the session. The participants needed to assign a phone number of a relative or friend for each conversation slot and send the table back to the research team latest three days before the testing date. If their next session was the isolation condition, they did not receive the conversation slots sheet, since in this condition no social contact was planned and the participants only needed to send an E-Mail with the activities they wanted to bring to the session. A reminder E-Mail was sent one day before the testing date, to inform the participants about behavioural constraints prior to the session and the meeting point. For the second and third session, the participants received a preparation E-Mail around one week ahead of the scheduled session and also a reminder E-Mail on the day before.

8.3.3. Location & Equipment

The study was conducted at the psychology faculty of the University of Vienna. A room with around 20 square meters in the basement of the faculty was used for the main part of the study. A smaller room next door served the experimenter to monitor each session and

the same room was used for the computer tasks that the subjects completed at the end of the experiment.

Some activities (books, riddles, drawing material, a rubik's cube, pencils) were provided in the room to prevent the participants from being bored. The individuals were also instructed to bring three to five non-social items from home. Social novels, pictures and music were considered as social content and were prohibited to be brought into the room. Computers or phones were also not allowed in the test space, since the participants could have contacted other people or used social media through these devices.

The participants could use a nearby toilet during the session, which was only accessible by them and the experimenter.

Figure 3

Experiment room

Note. Room the participant spent time throughout the sessions. Right table is the table seen in Figure 2. Left tables contain the activities.

8.4. Physiological measures

To measure stress responses, saliva was collected from the participants. Saliva is one option to obtain the stress indicator cortisol. It is a reliant hormone included in the hypothalamus-pituitary adrenal (HPA) stress reaction (Aktories et al., 2017; Huppelsberg et al., 2009; Klinke et al., 2010). The cortisol levels were measured at nine timepoints during the main testing period in the isolation or the neutral setting. The morning awakening cortisol levels of the participants after each session were additionally acquired. This aimed to measure a delayed stress response to social isolation.

The saliva samples were collected with the SaliCap (IBL International, Hamburg, Germany), which are small cups developed for this purpose. After the collection the saliva samples were immediately stored in a freezer at -20 degrees, until the biochemical analysis. For this analysis, the saliva samples of sixteen participants were included. For each participant nine samples during the sessions and two the morning after, were acquired. Considering that just two conditions (isolation and neutral) will be compared, this sums up to 22 saliva samples per participant and 352 saliva samples in total.

To measure physical arousal, a heart rate monitor chest strap Polar H10 (Polar Electro, Finland) was used to measure the heart rate throughout the whole experiment, to capture the immediate stress response of the autonomic nervous system (Ulrich-Lai & Herman, 2009). The participants wore the heart rate belt straight below their breast and continuously till the very end of the session. The heart rate was recorded in beats per minute.

8.5. Self-report questionnaires

Self-report questionnaires were used to measure mood and motivational states. Every item and question was collected through an ecological momentary assessment (EMA). EMAs allow repeated measurements of subjects' experiences in real time over periodic intervals. This aims to reduce recall biases and enhances the validity of the acquired values (Shiffman et al., 2008). For this study an iPod was used as EMA device and all notifications were presented in German since the experiment was conducted with a German speaking sample. For the thesis, the questions are translated to English. When referring to the time in figures and tables the German twenty-four-hour system is used to diminish misunderstanding of the measurement times in the graphs. Three different lengths of questionnaires were assessed thought-out the session which are described below.

The constructs, *stress*, *anxiety*, *controllability* and *avoidance* were assessed every hour throughout the session at nine time points. The answers could be given on a visual analogue

scale (VAS) which ranged from 0-100 (vonDawans et al., 2011). The first item was included to assess the perceived state of stress, whereas the other scales are used to detect subjective stress-responses.

Anxiety was measured with the question "*How anxious do you feel at the moment?"* with the answer option *"no fear" to "great fear"* ranging from VAS 1-100. The answer scale for *controllability, stress* and *avoidance* consisted of the same answer options *"not at all"* to *"very much"*, with the VAS 0-100. *Controllability* was measured with the questions *"How much do you have the situation under control?, stress* with the question *"How stressed do you feel?"* and *desire to leave* with the question *"How strong is your need to leave this situation?"* (vonDawans et al., 2011). These questions were asked every hour throughout the session and ensembled the shortest version of the questionnaire.

The majority of the other questionnaires were answered by the participants at five time points throughout the session. These questionnaires were presented every two hours, beginning with the start of the session at 10:55 am and continuing with 12:55 pm, 2:55 pm, 4:55 pm and 6:55 pm. The questionnaires asked at five times included the following;

The Multidimensional Mood Questionnaire German (MDBF; short form A and B) (Hinz et al., 2012), which assesses the mood in three dimensions; good – bad mood (GB), wakefulness – tiredness (WT), and calmness – restlessness (CA). Some scales had an opposed polarity and are indicated with a small "u" in the list below. The answers were recorded with a 5-point Likert scale starting with 1 – "not at all" and ending with 5 – "very much". With this psychological test instrument, the general emotional state was measured including the valence (good-bad) and two levels of arousal (energetic arousal and tense arousal).

The short form A consisted of these twelve items, which were presented in this order: content (GB), rested (WT), restless (CAu), bad (GBu), worn-out (WTu), composed (CA), tired (WTu), great (GB), uneasy (CAu), energetic (WT), uncomfortable (GBu), relaxed (CA). The short form B consisted of twelve equivalent items that are exchangeable with the short form A after being united in the three dimensions. The items of short form B were presented in the following order: sleepy (WTu), good (GB), at ease (CA), unhappy (GBu), alert (WT), discontent (GBu), tense (Cau), fresh (WT), happy (GB), nervous (CAu), exhausted (WTu), calm (CA).

Depending on a participant's ID being even or odd the MDBF questionnaire was presented at different time points. Participants with odd IDs received the short form A at 10:55 am, 2:55 pm, 6:55 pm and version B at 12:55 pm and 16:55 pm and participant with even IDs received the versions in a reversed order. The two different versions were included to prevent

memory effects of the questions and a memory bias. The English version of the questionnaire can be found on this website: https://www.metheval.uni-jena.de/mdbf.php.

Further, the Single-item ratings of desire for food, desire for social contact and perceived levels of hunger, loneliness and boredom were assessed at five time points during the eight-hour experimental period. All answers to these single-item ratings were given on a visual analogue scale (VAS), which ranged all from 0-100. Desire for food and social contact were answered from "not at all" to "very strong" with the questions „*How strong is your desire for food at the moment?"* and "*How strong is your desire for social contact right now?".* Hunger, loneliness and boredom ranged from *"not at all"* to *"very"* and included the three single-item scales which directly asked for the states with the following questions: *"How hungry do you feel at the moment?"*, "*How lonely do you feel at the moment?*" and *"How bored do you feel at the moment?".* These questions were included to examine the subjective levels of the main study aims. The question of boredom levels is assessed to ensure that the mood changes are not influenced by too high levels of boredom.

The second mood questionnaire, Profile of Mood States (POMS) (Dahlbert, 1992) and the desire for the phone or internet was assessed three times every fourth hour at; 10:55 am, 2:55 pm and 6:55 pm. The questions "*How strong is your desire to use your smartphone?" and "How strong is your desire to use the internet?"* with the answering scale ranging from *"strongly disagree" to "strongly agree"* on a visual analogue scale from 0 to 100 assessing the motivation to use the phone or internet. These questions were included since the phone and internet gives the chance to connect with other individuals and it is nowadays one of the main ways to interact between humans.

The short version of the Profile of Mood States (POMS) was included to examine different nuances of mood states in more detail since social isolation could be linked to depression and anxiety in humans (Haney, 2003). Social interactions further were shown to have a stronger influence on negative mood than positive emotions (Newsom et al., 2003). The POMS consists of nineteen different emotion adjectives that were answered on a 7-point Likert scale from 1 – "not at all" to 7 – "very strongly". The nineteen items are merged into five subdimensions: sadness (SAD) with three items, hopelessness (HOP) with three items, fatigue (FAT) with four items, positive mood (POS) with six items and anger (ANG) with three items. The emotions were assessed in the following order: angry (ANG), worn-out (FAT), unhappy (SAD), sad (SAD), pleasant (POS), afflicted (SAD), joyful (POS), hopeless (HOP), tired (FAT), angry (ANG), cheerful (POS), discouraged (HOP), happy (POS), exhausted

(FAT), cheerful (POS), desperate (HOP), furious (ANG), weakened (FAT), amusing (POS). The initials in the brackets indicate to which dimension the emotions belong.

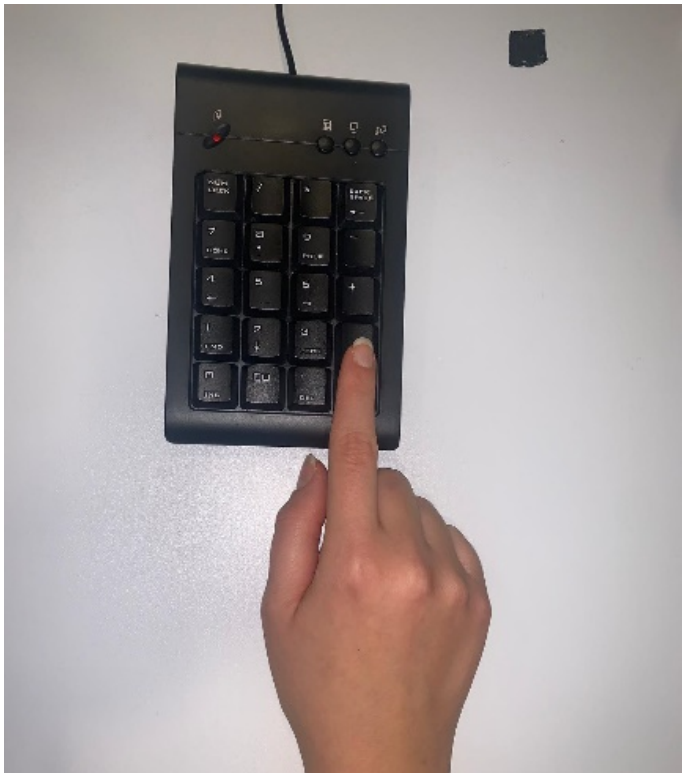
8.6. Executive function tasks

Three cognitive tasks are included in this experiment to assess possible changes of social isolation on motor control (Finger tapping task), cognitive inhibition (Go/No go task) and working memory (N-back task).

The Finger Tapping Test (FIT) assesses the motor speed of a participant (Carone, 2007). The task requires the participants to tap the "Enter" key on the keyboard as much as possible within ten seconds using their index finger (Figure 4). This is repeated five times with the dominant hand and five times with the non-dominant hand, with a five-second break in between the switch of hands. The average of the five trials for the dominant hand and the non-dominant hand ensembles the motor speed score for each hand.

Figure 4

Finger tapping task (FIT)



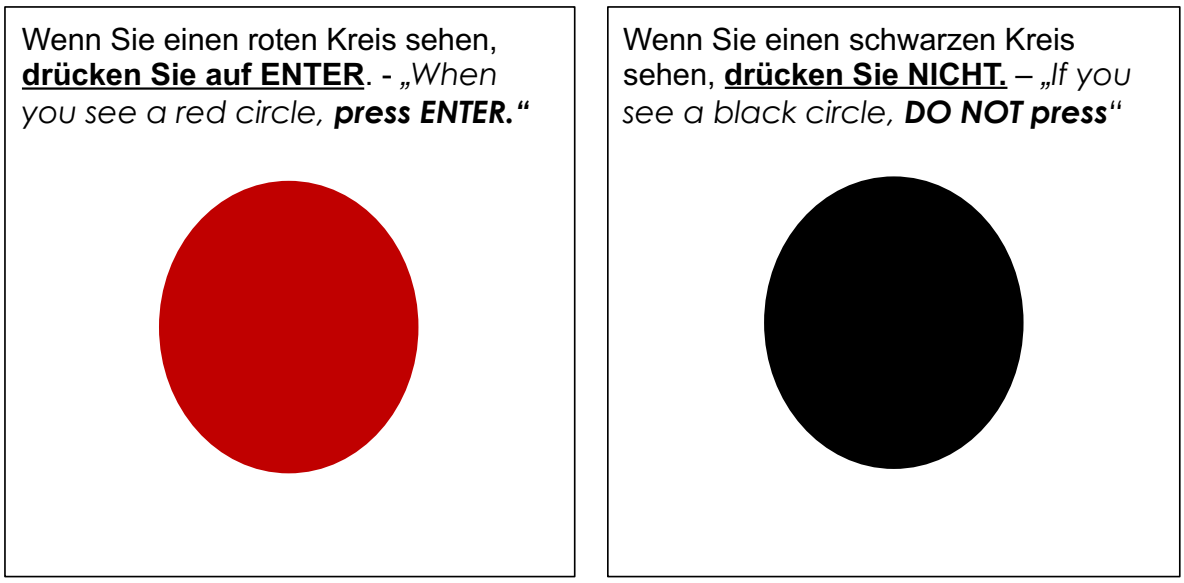
Note. Keyboard used for the FIT. The participants were requested to hold hand like this and press the "Enter" key as often as possible within the trials.

The second task is called Go/No-go and assesses the inhibition control (Kertzman et al., 2011; Nestor et al., 2011; Verbruggen & Logan, 2008). The successful mastering requires

the participants to press the "Enter" button whenever a red circle is seen (Go signal) and not press "Enter" when a black circle appears (No-go signal) on the screen (Figure 5). The circles are shown very fast and the challenge is to inhibit a response when the no-go signal (black circle) is seen. A commission error happens, if the individual is not able to withhold a response to the No-Go signal (black circle) and an omission error if a participant is falsely not pressing to a Go signal (red circle) (Meule, 2017). The whole task lasted around eight minutes with a short break of twenty seconds in the middle of the task.

Figure 5

Inhibition control task – Go/No-go

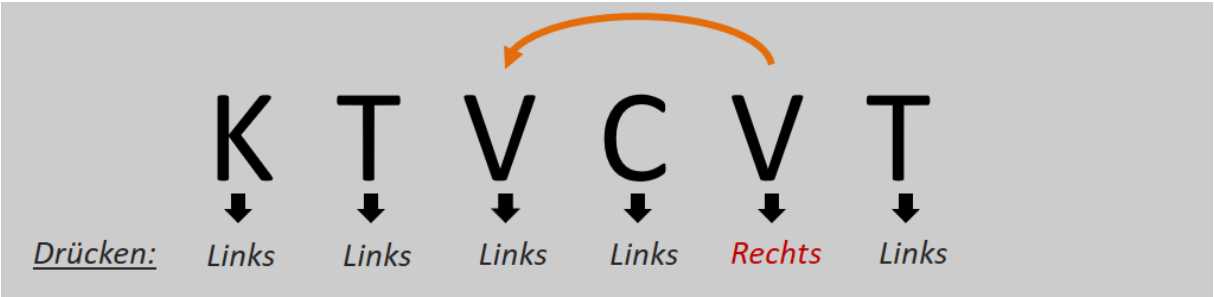


Note. Participant were requested to press "Enter" when seeing a red circle and inhibit a reaction when seeing a black circle.

The last exercise of the experiment was the N-Back task (Jaeggi et al., 2010), which measures the working memory. It consisted of three parts, one control exercise that required the participant to press the key "arrow right" every time they saw the letter "X" on the screen, whereas for every other letter they needed to press the key "left arrow". This task has a very low difficulty level, so it was used as a control exercise to clarify that the participants understood the task and were confident with the procedure. The other two parts of the task measured the working memory. In the 2-Back task, the participants needed to press the key "right arrow" when the letter appearing on the screen was the same as the one visible two letters before. In any other case the participants were supposed to press the key "left arrow" (Figure 6).

Figure 6

Working memory task – 2-Back (N-Back)



Note. Figure shows the 2-Back task as an example of the N-Back tasks. "Drücken" = press. "Links" = left. "Rechts" = right. Participants needed to press the "right-arrow" key, if a letter appeared two positions after, again. For all other circumstances they needed to the press the "left-arrow" key.

The last task named 3-Back, worked similarly as the previous; the participants needed to press the key "right arrow" when the letter that appeared on the screen was the same as the letter, seen three positions before, for every other option they needed to press the key "left arrow".

The whole N-Back task consisted of several repetitions of the three subversions (X-Now, 2-Back, 3-Back), which alternated randomly. At the beginning of each round, it was indicated to the participant which task came after. In between the different subtasks was a short break and the whole exercise lasted around fifteen minutes. Mistakes are counted if a wrong response to a letter was given (MISS) or if the individuals needed too much time to react (Timeout).

9. Analytic plan and statistical methods

For the analysis of the subjective questionnaire data (MDBF, POMS, VAS), the cortisol data throughout the session and the heart rate data a mixed effects model analysis was used, in particular a random intercepts and slopes model. With this approach hierarchical data can be analysed and missing values do not present a problem. The used random intercepts and slopes model allows to assess the impact of longitudinal independent variables on a dependent variable, which was the case in this study. The influence of the two comparative sessions (isolation and neutral) and time of the session on mood states, cortisol levels and heart rate were assessed in the analysis. For the random intercepts and slopes model, the R function lmer of the package lme4 was used (Kuznetsova et al., 2017) and mainly the interaction effect of time and condition will be discussed in more detail in the result part since it comprises the main

interest. For the analysis of the Cortisol Awakening Response (CAR) and the cognitive tasks (FIT, Go-No-Go, N-Back) a paired t-Test was applied as the data was not longitudinal.

The data analysis was completely conducted with the open-source programming language R (R Core Team, 2019) and started with the preparation of the data for further statistical calculations. For the mood questionnaire MDBF some of the Likert-scale items needed to be reversed. Subsequently they were assigned to the three dimensions. The data of the POMS was also summarized to the five dimensions. The next step included a graphical exploration.

After, a random intercepts and slopes model was fit for the mood questionnaires (MDBF, POMS) and for all visual analogue scale questions. Each dimension of the MDBF and POMS was treated as an outcome variable of the model. The predictors used for the model were: the time, the condition (group = isolation/neutral) and the interaction between the condition and time. The same was done for the visual analogue scale questions, with the difference that the outcome variable was the score obtained on the visual analogue scale.

For each model additionally to the standard statistical results, the effect size Cohen's *d* was calculated in R. The model diagnostic for every random intercepts and slopes model was assessed and resulted in some violations of the normal distribution of the residuals. Since mixed-effects models' estimates are robust with respect to the model's assumptions, estimates were not considered to be severely biased (Schielzeth et al., 2020). The assumptions of "linearity of predictors" and "homogeneity of variance" were mostly fulfilled for all random intercepts and slopes models which were fitted to the data. To check for outliers, boxplots were evaluated for the mood questionnaire dimensions (MDBF, POMS) and for each visual analogue scale question. All data points laying four standard deviations below or above the mean were excluded based on Chebyshev's theorem. This theorem assures that with k = 4 at least 93,75% of the data lies within 4 standard deviations from the mean, if the data is not normally distributed. The analysis conducted on this reduced set of data did not show any remarkable difference compared to the original data, therefore only the analysis of the whole data is presented in the following results paragraph. Moreover, the sample size is already very small, thus removing data points might lead to an even less representative sample. This choice is further justified from the fact that it is not expected to observe implausible data from Likert-scales and visual analogue scales.

A similar analysis was conducted for the cortisol levels acquired in the experimental conditions. After a graphical examination, a random intercepts and slopes model was applied to the data gathered during the session. Since it is assumed that the cortisol release follows a log normal distribution, the outcome variable of the model was log transformed. The model

diagnostics analysis resulted only in a violation of the assumption of “normal distributed residuals”. The assumptions of “linearity of predictors” and “homogeneity of variance” were fulfilled.

To assess the value of the cortisol levels of the awakening response, the participants were required to produce two saliva samples, one straight after waking up and one thirty minutes later. The value of the cortisol awakening response was obtained by subtracting the cortisol level of the second sample from the value of the first one. To calculate the difference of the two conditions a paired t-test was conducted. An effect size of Cohen's *d* was estimated for the difference between the conditions and the morning awakening response between the social isolation and neutral session. The boxplot analysis showed some extreme values in both conditions. However, these values were not considered extraordinary.

The analysis of the heart rate data was slightly different. As the heart rate data was measured for each second, from the start to the end, each participant had a large number of observations. For each second an average beat per minute (bpm) was recorded, including the data around that second. To obtain feasible data for the mixed model analysis, it was decided to take the average heart rate of every hour for a total of eight hours. The heart rate was started to be measured approximately twenty to thirty minutes before the session of each participant. Therefore, the first hour of heart rate data was excluded from the analysis, since the collection of the data was starting prior to the session. In addition, no difference is expected between the groups at the start. Some graphs were plotted to investigate whether there were any remarkable differences between the two conditions and a histogram to inspect the distribution of the heart rate. A random intercepts and slopes model was fit to the data to verify if there is any difference between the heartbeats in the isolation and the neutral condition. Lastly the model diagnostics were assessed revealing a slight violation of “normally distributed residuals”.

The statistical analysis of the cognitive tasks after the session was performed using a paired t-test to verify, if there is any significant difference between the mean of the isolation and the neutral condition. For the Finger Tapping Task a separate calculation was done for each hand. The means of the five rounds of a participant were calculated for both hands and compared between the conditions.

In the Go-No-Go inhibition control task the ratio of mistakes over the total number of trials was computed for each condition. A paired t-test was conducted to evaluate if there was any difference between the error ratio of the two groups.

For the working memory task, the percentages of the mistakes (MISS, Timeout) to the

total number of trials were assessed and a paired t-test was conducted for the 2-Back and 3-Back task comparing the mean differences between the two conditions. For all three cognitive tasks effect sizes (Cohen's *d*) were calculated.

All effect sizes (Cohen's *d*) are rounded to two decimal points. The Cohen's *d* of 0.2 is considered a small effect, the value of 0.5 as a medium effect and 0.8 as a large effect (Cohen, 1977). P values below .05 are classified as significant and indicated with " * ", <.01 with "**" and <.001with "***".

9.1. Missing data

As mentioned before did the circumstances regarding the COVID-19 pandemic led to the prolongation of data collection. For this reason, the statistical analysis was conducted on a reduced sample resulting in an underpowered study. Considering the smaller sample size, significant results are harder to detect and therefore also the effect sizes for not significant results are indicated in the following paragraph. Apart from the reduced sample size just a few missing values were present of the heart rate data. For the mixed effect model technique that was used, missing values are not problematic.

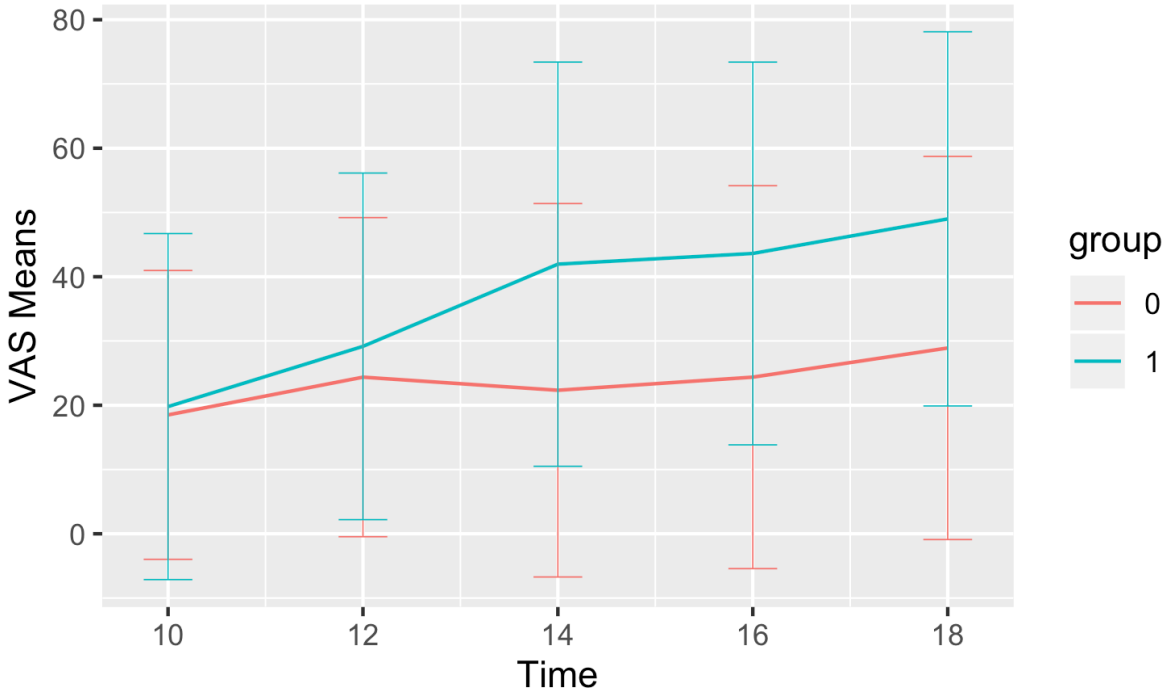
10. Results

The statistical analysis of the questionnaire data (n = 24) during the session included a series of random intercepts and slopes models to assess the interaction of the conditions over time on mood states. Also the cortisol data of the session (n = 16) and heart rate data (n = 24) will be analysed through a random intercepts and slopes model. Mainly the interaction effects of the random intercepts and slopes model are discussed in more detail in the result part, for the main effects of the variables condition (Group) and time (Hour) see material in the attachments. The cortisol awakening response (CAR) (n = 16) and the cognitive tasks (FIT, Go-No-Go, N-Back) (n = 24) are assessed with a paired t-Test.

Manipulation check: The manipulation check was fulfilled as the visual analogous scale for social desire ("*How strong is your desire for social contact right now?"*) resulted in a significant difference between the isolation and neutral condition over time $F(23.11) = 5.37$, $p = .03$*, Cohen's $d = 0.96$ (Figure 7, Table 1). These statistical values indicate a very strong significant effect of the isolation condition on the desire for social contact. It shows the only significant effect within this study, verifying the hypothesis that social isolation leads to a higher need for social contact than the neutral condition.

Figure 7

Desire for social contact comparing isolation and neutral condition



Note. Line graph showing the averages of the VAS for social desire over the whole eight experimental hours (n = 24). The Y-axis shows the VAS scale averages ranging from 0-100 and the X-axis the five measurement times without the indication of the minutes. The blue line (group=1) indicates the values throughout isolation condition and the red line (group= 0) throughout neutral condition. Error bars can be below zero because the SD is sometimes bigger than the mean. A significant difference appears over the experimental time between the two sessions.

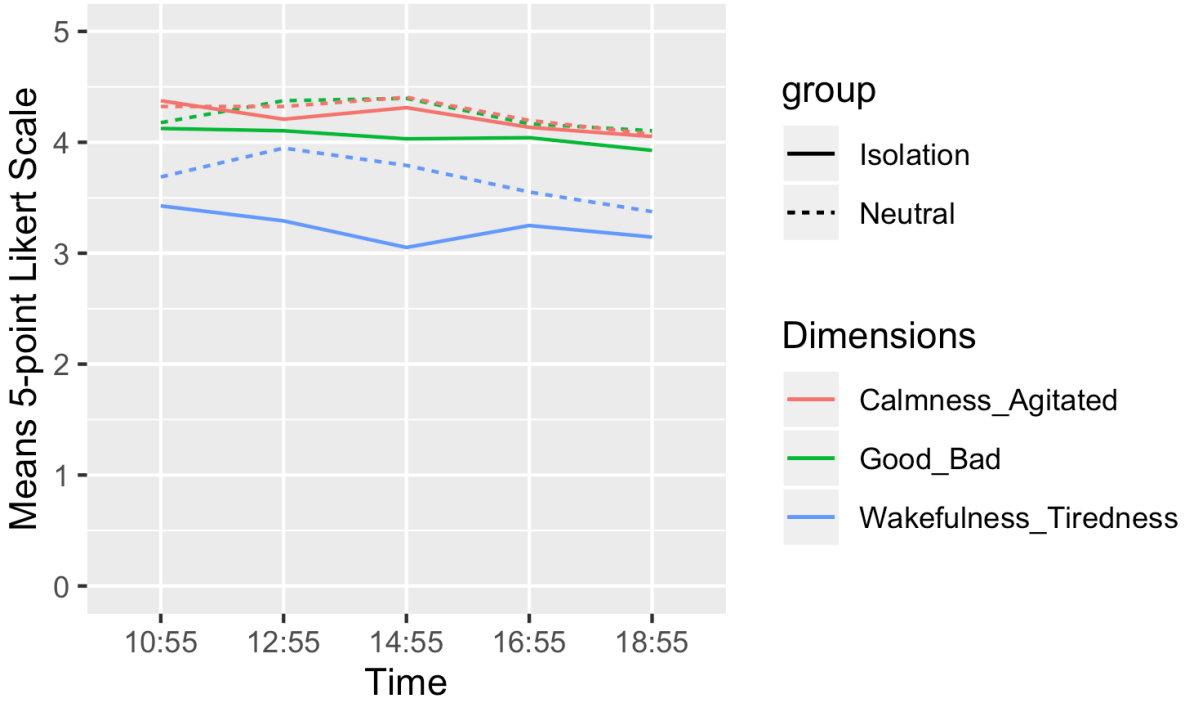
Emotional states: The analysis of the tools to assess variants around emotional states did not show any significant effects between the two conditions over time. The interaction effect of the Multidimensional mood questionnaire (MDBF) resulted for the dimension "good and bad mood" in a non-significant difference $F(23.14) = 0.07$, $p = .79$, Cohen's $d = -0.11$ (Figure 8; Figure 10). Also, the interaction effects of the other two dimensions did not show significant differences between the groups neutral and isolation. In the "wakefulness and tiredness" dimension the values $F(124.97) = 0.48$, $p = .49$, Cohen's $d = 0.12$ were present and for the dimension "calm and agitated" $F(22.51) = 0.09$, $p = .77$, Cohen's $d = -0.13$ (Figure 8). The standard deviations (SD) for the dimension "good-bad" ranged from 0.68 to 0.81 throughout the isolation condition and from 0.52 to 0.87 in the neutral condition, for the dimension "wakefulness and tiredness" from 0.78 - 0.94 during social isolation and from 0.65 -

0.98 throughout the neutral condition. The SD of the third dimension “calm and agitated” ranged from 0.44 to 0.77 in isolation and from 0.49 to 0.83 in the neutral session. The SD are mentioned because error bars in Figure 8 would hinder clarity.

The main effect of the variable time (Hour) appeared to be significant in the dimension “calm-agitated” $F(24.77) = 4.28$, $p = .049$*. This result of the main effect (Hour) implies that in both session a similar significant (calm-agitated) change over the eight-hour time-period appeared.

Figure 8

Mood questionnaire – MDBF comparing isolation and neutral condition on all dimensions



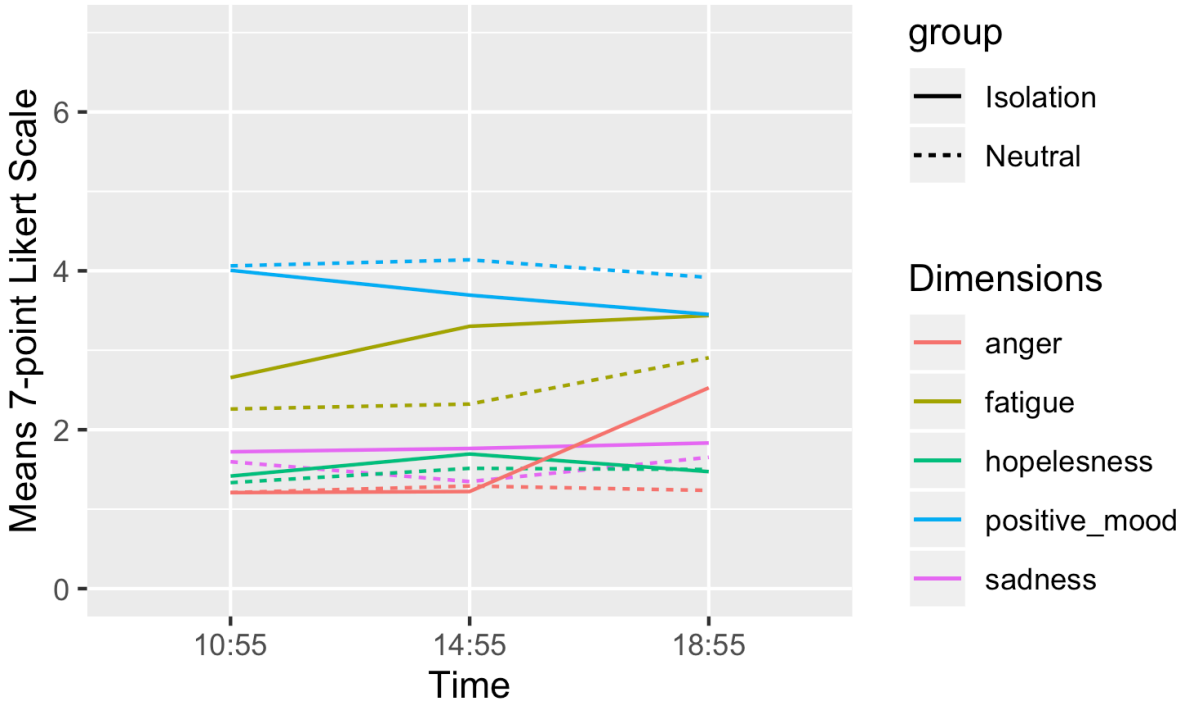
Note. Line graph showing the averages of the MDBF over the whole eight experimental hours (n = 24). The Y-axis shows the five-point Likert scale averages and the X-axis the five measurement times. Solid lines indicate the Likert values throughout isolation condition and dashed lines throughout neutral condition. Green lines comprise the dimension *good-bad* (GB), red lines the dimension *calmness-agitated* (CA) and blue lines the dimension *wakefulness-tiredness* (WT). SD throughout isolation condition: SD(GB) = 0.68 - 0.81; SD(WT) = 0.78 - 0.94; SD(CA) = 0.44 - 0.77. SD throughout neutral condition: SD(GB) = 0.52 - 0.87; SD(WT) = 0.65 - 0.98; SD(CA) = 0.49 - 0.83.

The second mood questionnaire (POMS) assessing different nuances of mood during the session did not show any significant interaction effects either on any of the five dimensions (Figure 9). The values resulted for the sub dimension sadness in $F(27.15) = 0.05$, $p = .83$, Cohen's $d = 0.09$, for hopelessness in $F(32.01) = 0.16$, $p = .69$, Cohen's $d = -0.14$, for fatigue in $F(59.83) = 0.07$, $p = .79$, Cohen's $d = 0.07$, for positive mood in $F(43.87) = 1.99$, $p = .17$, Cohen's $d = -0.43$ (Figure 10) and for anger in $F(23.66) = 0.79$, $p = .38$, Cohen's $d = 0.37$. These results present the change, over the time between the two sessions regarding mood (Figure 9). The standard deviations (SD) for the dimension sadness ranged from 0.85 - 1.02 throughout the isolation session and from 0.56 - 0.89 in the neutral condition, in the dimension hopelessness from 0.67 - 0.87 in isolation and from 0.56 - 0.86 in the neutral condition, for the dimension fatigue from 1.40 - 1.52 during the isolation session and 1.02 - 1.30 in the neutral condition, for positive mood between 1.00 - 1.25 in isolation and between 0.95 - 1.37 in the neutral condition and lastly for anger from 0.43 - 6.72 throughout isolation and from 0.47 - 0.90 during the neutral session. The standard deviations are described because error bars are not indicated in Figure 9 to enhance clarity.

In no dimension of the mood questionnaires (MDBF/ POMS) significant changes appeared over the eight-hour period comparing the isolation and neutral condition. Nevertheless one main effect of the variable time (Hour) was significant for the dimension fatigue $F(22.76) = 9.15$, $p = .006$** indicating that in both session the fatigue levels rose over the experimental time.

Figure 9

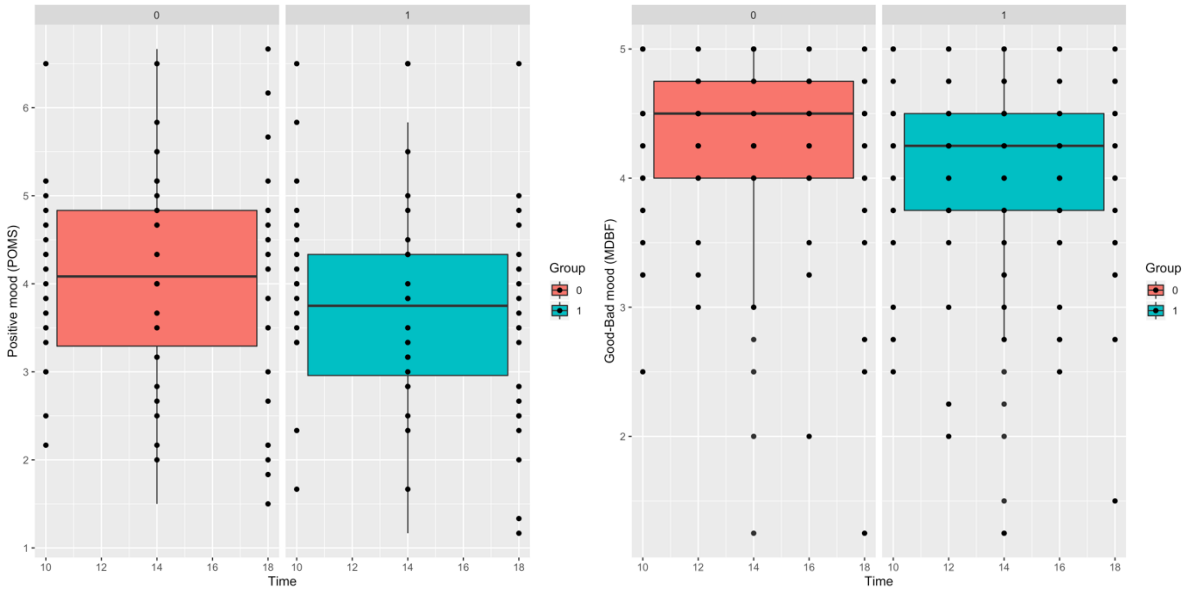
Mood questionnaire – POMS comparing isolation and neutral condition on all dimensions



Note. Line graph showing the averages of the POMS over the whole eight experimental hours (n = 24). The Y-axis shows the seven-point Likert scale averages and the X-axis the three measurement times. Solid lines indicate the Likert values throughout isolation condition and dashed lines throughout neutral condition. Colours indicate the dimensions: red lines = *anger (ANG)*, light-green lines = *fatigue (FAT)*, dark-green lines = *hopelessness (HOP)*, blue lines = *positive mood (PM)* and pink lines = *sadness (SAD)*. SD throughout isolation condition: SD(ANG) = 0.43 - 6.72; SD(FAT) = 1.40 - 1.52; SD(HOP) = 0.67 - 0.87; SD(PM) = 1.00 - 1.25; SD(SAD) = 0.85 - 1.02. SD throughout neutral condition: SD(ANG) = 0.47- 0.90; SD(FAT) = 1.02- 1.30; SD(HOP) = 0.56 - 0.86; SD(PM) = 0.95 - 1.37; SD(SAD) = 0.56 - 0.89.

Figure 10

Boxplots comparing the mood dimensions: positive mood (POMS) and Good-Bad (MDBF)



Note. Boxplots of the dimensions *positive mood (POMS)* right and *good-bad mood (MDBF)* left (n = 24). Showing the differences of emotions between the isolation (blue = 1) and neutral (red = 0) condition. The Y-axis indicating the time points without the minute declaration.

Visual analogue scales assessing related aspects around emotional states: The visual analogue scale (VAS) questions assessed various other contents around mood during the experiment. Also, a random intercepts and slopes model was used to analyse the interaction of the session and time of the different psychological aspects. No significant interaction effect of the experimental manipulation appeared in ten of the eleven visual analogue scale questions. The exception which resulted in a significant difference of the two groups throughout the sessions was the manipulation check of the perceived wish for social contact (Figure 7). Table 1 shows an overview of all the effect sizes (Cohen's *d*) and the p-values. Three main effects of the variable time (Hour) were significant including the VAS *"How strong is your need to leave this situation?"* $F(23.05) = 19.97$, $p = <.001$*** and *"How bored do you feel at the moment?"* $F(23.43) = 19.55$, $p = <.001$*** implying that in both session the boredom levels and desire to leave the situation significantly changed over the experimental period (8h). The other values of the interaction effects, main effects and statistical parameters (F value; df) of all visual analogue scale questions can be found in the attachments.

Table 1
The interaction effects between time and condition of the random intercepts and slopes model of all visual analogue scale questions (VAS)

	Cohen's *d* *(interaction effect time:condition)*	**p-value**
VAS asked every hour (9 times)		
"*How anxious do you feel at the moment?"*	-0.07	.87
"How much do you have the situation under control?"	0.01	.98
"How stressed do you feel?"	0.05	.91
"How strong is your need to leave this situation?"	0.06	.89
VAS asked every second hour (5 times)		
„*How strong is your desire for food at the moment?"*	-0.07	.84
"*How strong is your desire for social contact right now?"*	0.96	.03*
"How hungry do you feel at the moment?"	0.18	.58
"*How lonely do you feel at the moment?*"	0.49	.24
"How bored do you feel at the moment?"	0.44	.21
VAS asked every third hour (3 times)		
"*How strong is your desire to use your smartphone?"*	-0.04	.92
"How strong is your desire to use the internet?"	0.22	.59

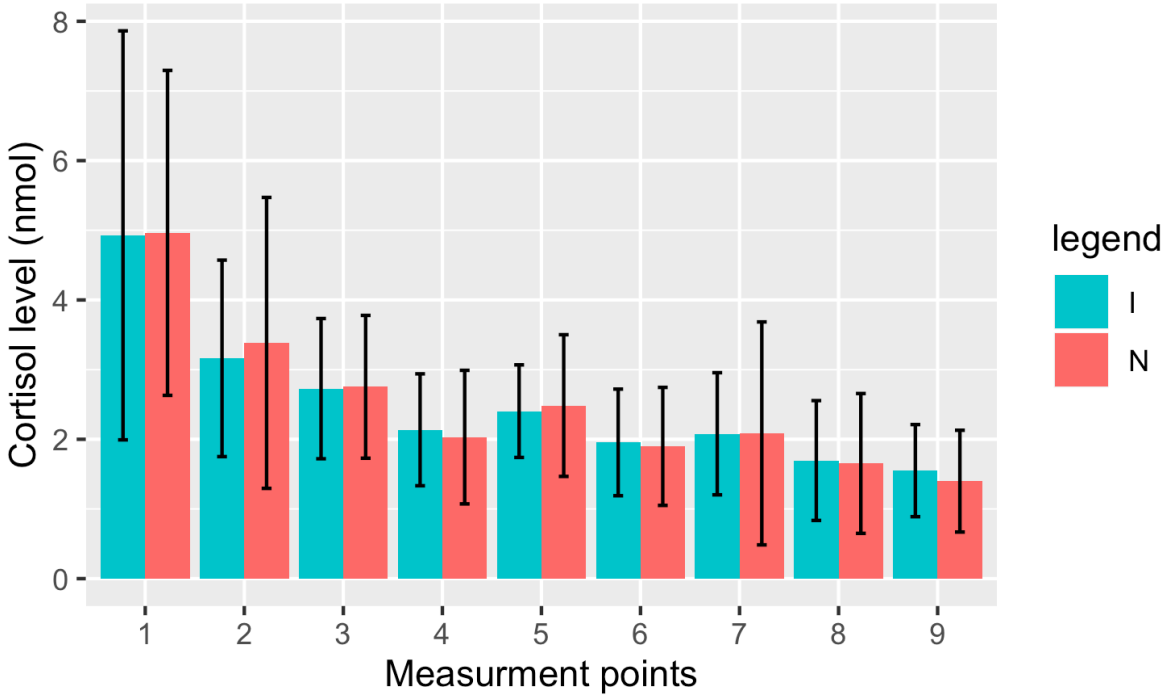
Note. <.05*

Stress – Cortisol response: The cortisol analysis (log(lmer)) which was conducted on a smaller sample size (n=16) did not result in a significant interaction effect of cortisol throughout the two conditions over the time F(28.40) = 0.49, p = .49; Cohen's d = -0.26 (Figure 11). The main effects of the cortisol levels of the condition (Group) were F(29.98) = 0.12, p = .74 and the main effect of time (Hour) F(28.40) = 134.72, p = <.001***. The main effect of time shows a significant effect indicating that the cortisol levels changed similarly over

time during both sessions which stays in line with the literature of decreasing cortisol release throughout the day passing (Aktories et al., 2017).

Figure 11

Cortisol levels throughout the sessions comparing isolation and neutral condition



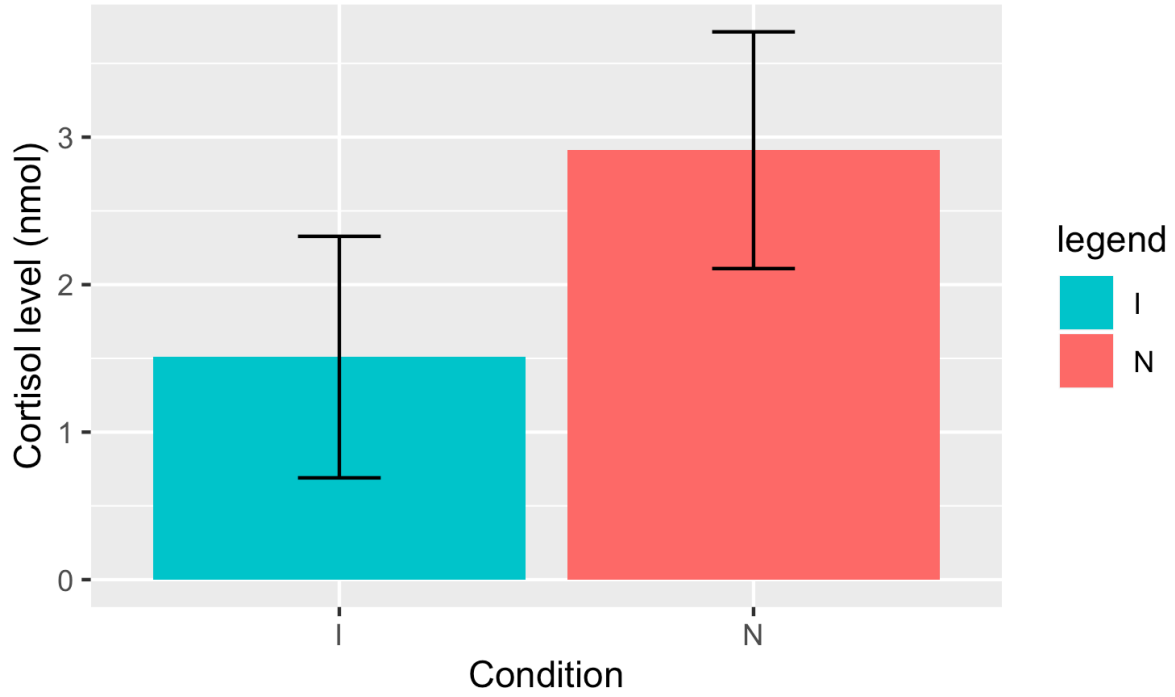
Note. Comparison of cortisol levels between isolation (red) and neutral (blue) conditions throughout the experimental session (n = 16). Y-axis indicating the cortisol levels in the saliva (nmol/l) and X-axis showing the measurement points starting at 10:55 am till 6:55 pm. Error bars +/- 1 SE.

The cortisol awakening response (CAR) which was calculated with a paired t-test shows following values $t(15) = 1.69$, $p = .11$ and a Cohen's d effect size of 0.90. This result even though not significant shows a higher cortisol awakening response after the participants experienced the neutral condition of the experiment. The difference is also visible in the bar chart (Figure 12).

No significant influences over the eight-hour experimental time of the social isolation compared to the neutral condition was found in the cortisol levels, despite some notable differences in the cortisol awakening response.

Figure 12

Cortisol awakening response after isolation and neutral session



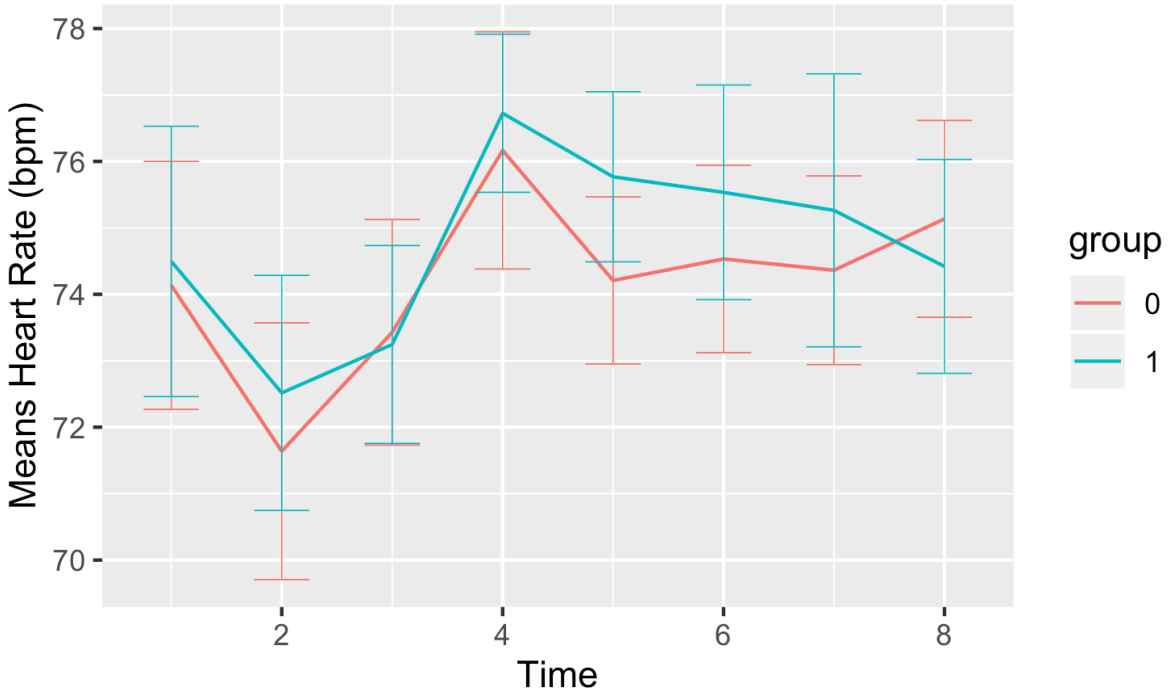
Note. Cortisol awakening response after the isolation (red) and neutral (blue) sessions (n = 16). Y-axis indicating the cortisol levels in the saliva (nmol/l) and X-axis showing the condition experienced the prior day. Error bars +/- 1 SE.

Heart rate: The physical arousal measured through the heart rate did not indicate a significant difference between the isolation condition and the neutral condition. The heartbeat values per minute resulted in F(60.99) = 0.09, p = .77, Cohen's d of 0.08 for the interaction effect, which reflects a not significant difference of the means. A second random intercepts and slopes model was done excluding the first four hours of the experiment to assess if a different heart rate appeared after four hours into the experimental session resulting in the interaction effect values F(62.85) = 0.37, p = .54, Cohen's d of -0.15. The main effect of time (Hour) showed a significant effect F(25.50) = 7.25, p = .01* indicating a similar hear beat pattern throughout both sessions over the experimental time (Figure 13).

Seeing from the total values the average heartbeat over the whole eight experimental hours in the neutral condition (74,17 bpm) is slightly lower than during the isolation (74,18bpm) session, which is also visible in the graph (Figure 13). Nearly from the beginning to the end of the session the heart rate was slightly higher within the isolation condition but never significantly. The manipulation of induced isolation did not significantly influence the physical arousal (heart rate) in comparison to the neutral condition.

Figure 13

Hear rate (HR) throughout the experiment of isolation and neutral session



Note. Heart rates (bpm) throughout the isolation (blue = 1) and neutral (red = 0) conditions (n = 24). First hour was deducted from analysis since the HR-belt was placed on the participant before experiment started. X-axis indicating the average heart rate and Y-axis showing the hours.

Cognitive tasks: The paired t-test assessing all three cognitive tasks after the session did not show significant results. The Finger Tapping motor control task for the right hand showed the values $t(23) = 0.84$, $p = .41$, Cohen's $d = 0.35$ and for the left hand $t(23) = 0.88$, $p = .39$, Cohen's $d = 0.37$ indicating no significant difference in motor control between the two conditions. The absolute values of participants had on average around half a tap more for both hands in the neutral compared to the isolation condition. The participants achieved 30.99 taps in the neutral and 30.43 taps in the isolation condition with the right hand and 26.79 taps in the neutral versus 26.15 taps in the isolation session with the left hand.

The Go-No-Go task testing the inhibition control resulted in $t(23) = 1.55$, $p = .13$, Cohen's $d = 0.65$. This result shows the number of mistakes over the number of trials were higher in the neutral group even though no significant difference appeared. In absolute numbers, there were 100 more mistakes in 12000 trials made in the neutral condition than in the isolation session.

The N-Back task which assesses the working memory of the two groups resulted in $t(23) = 0.38$, $p = .71$, Cohen's $d = 0.65$ of the 2-Back subtest. The results for the 3-Back task are $t(23) = 1.54$, $p = .14$, Cohen's $d = 0.64$. In both conditions the weighted mistakes were higher in the neutral condition even though the results are not significant. The total values in the 2-Back task show 205 mistakes in the neutral compared to 193 mistakes in the isolation condition out of 2400 trials. In the 3-Back subtest a ratio of 400 mistakes in the neutral compared to 334 mistakes in the isolation session over 2400 trials were present.

The results of the control task X-Now did not show abnormalities which implies that the participants understood the task and that the results of the 2-Back and 3-Back task are valid for interpretation. The social isolation period of eight hours did not result in significant differences of the motor control, inhibition control or working memory despite the implication of small to middle effect sizes of the Cohen's *d* values.

11. Discussion

The main purpose of this study was to investigate whether the experimental induced state of social isolation lasting eight hours has an impact on the mood states and physical stress response. The hypotheses derived accordingly to the literature suggest that social isolation of eight hours will lead to more negative mood than the neutral condition including social interactions. Moreover, a higher physical stress response was expected during the isolation condition and a higher cortisol awakening response afterwards in comparison to the neutral session. Contrary to the predictions (Clark & Watson, 1988; Cruwys et al., 2013, Eisenberger et al., 2003; Eisenberger, 2015; Kross et al., 2011; McIntyre et al., 1990; McIntyre et al., 1991; Newsom et al., 2003; Rook, 2001; Vittengl & Holt, 1998) no significant difference in the mood levels between the two groups could be validated according to the findings within this study. The results gathered from the analysis of the dimensions good/bad (MDBF) and positive mood (POMS), show that slightly worse emotions were present in the perceived mood states of the individuals during social isolation. However, no significant distinction was assessed. The main explanation for a missing effect could be the very short time span of the isolation period. Given the low number of studies focusing on short-term effects of social isolation, it is not known yet from which timepoint it is expected to see a significant impact of social deprivation on mood. It is possible that periods of short-term isolation did not yet influence the emotions strongly enough as it does when humans feel lonely or in solitary confinement over a longer period (Gamman, 2001 as cited in Smith, 2006; Haney, 2003). Considering that the negative mood was slightly higher in the isolation condition maybe over a longer period a stronger difference will appear between the two conditions. Another explanation

might lay in modulating variables as the personality traits extraversion and introversion. An extravert is a person who seeks excitement, enjoys the company of people, likes to take risks and appears friendly in exchange with others (Parija & Shukla, 2014). In experiments, people with extrovertive traits could bear isolation situations less, in comparison to introverts (Francis, 1969; Tranel, 1962). Extraversion was also shown to be negatively correlated with loneliness (Saklofske & Yackulic, 1989). In another study which focused on brain functioning researcher found out that the connection between the left dorsolateral prefrontal cortex and loneliness was partly mediated by the influence of extraversion, which indicates that extraversion characteristics might play a role in the development of loneliness in humans (Kong et al., 2015). Considering these results extraversion should be controlled and be included as an influencing variable which mediates the connection between objective social isolation and the aversive experience of it. Taking the extravert and introvert levels into account in the analysis might result in significant differences between the isolation condition and the neutral condition already over a short period.

Contrary to expectations no differences in the physical stress response emerged between the two sessions. The cortisol levels throughout the isolation condition were very similar to the neutral condition. This finding stands against former research (Adam et al., 2006; J. T. Cacioppo et al., 2000; Doane & Adam, 2010; Grant et al., 2009; Steptoe et al., 2004) and various animal studies (Kanitz et al., 2004; Nation et al., 2008; Smith & French, 1997). Again, the main explanation could be the short social deprivation period which only lasted eight hours. Within this time frame no endocrine differences appear since physiological processes might not react so quickly to the aversive situation. The cortisol levels were minimally higher throughout the isolation condition but were so small that even with a full sample, it is not probable to obtain a noteworthy difference. Another explanation could be that women using oral contraceptives show less physical stress responses to psychological stress (Kirschbaum, Pirke et al., 1995). Considering that the majority of the sample used oral contraceptives a strong enough endocrine stress response might have been suppressed to detect a difference between the two sessions, whereas an effect could have been visible in women using other contraceptive methods or none at all. Moreover, animal studies with monkey show that different intensities of social stressors can impact the HPA-axis relational (Smith & French, 1997). It could be possible that the social deprivation condition did not present a severe enough stressor to show differences in the cortisol response. The participants were aware that the experimenter was sitting next door and it was possible to get in contact at any time, if the experiment wanted to be discontinued. The knowledge of a person close-by and the steady oppor-

tunity to contact it might have reduced the social derived stress. Furthermore, it might be possible that the two conditions of this study were not distinct enough to validate an effect in the physical stress response. A neutral condition including interactions with familiar people in person throughout the session might have resulted in a significant difference between the two groups. Nevertheless, the subjective question assessing perceived stress did not show any difference and rather support the obtained results and missing differences in cortisol levels.

The results of the morning awakening response contradict the predictions of previous studies (Adam et al., 2006; Doane & Adam, 2010; Grant et al., 2009) and a higher cortisol awakening response (CAR) was present after the neutral condition than after the social deprivation. It might be possible that the individuals adapted to a low stimulation environment throughout the social isolation period and their HPA-axis produced less cortisol, which reflected the CAR in the next morning. Alternatively, it can be hypothesised that the isolation period without social contact could have had a relaxing effect on the participants resulting in a reduced stress response the following morning.

In general, the two main hypotheses assessing the impact of short-term isolation on mood and stress responses are mainly based on studies with loneliness, which comprises the quality of social isolation and perceived feelings, whereas this study focused only on objective short-term isolation over eight hours. Inferring from the obtained outcome, perceived loneliness and acute objective isolation might result in other consequences even though they are highly correlated as shown in previous studies (Hawkley et al., 2008; Ruiz, 2007; Taylor et al., 2016). Long-term isolation might produce feelings of loneliness and only these circumstances lead to worse mood and higher cortisol levels in humans even if animal studies predict also a connection of objective social isolation and increased cortisol levels (Kanitz et al., 2004; Nation et al., 2008; Smith & French, 1997).

Concerning the first sub hypothesis no significant increase of the heart rate during the short-term isolation could be found in comparison to the neutral condition. This stands in contrast to the expectation but might reflect the missing effects in the physical and subjective stress response which was just mentioned. An increased heart rate is a consequence of the immediate stress response (Ulrich-Lai & Herman, 2009) but if less stress is experienced in the social isolation condition, as stated by the cortisol awakening response data, an increased heart rate is not very likely. However, a sudden increase was visible in both groups after a bit more than four hours and the heart rate in the isolation group stayed a bit higher in the second half of the experiment. The total averages between the two sessions underline this outcome since the heartbeat throughout the isolation session was one bpm higher in comparison to the

neutral session. It could be hypothesized that a longer social deprivation period could result in a difference.

The hypothesis of an increased desire for social isolation in the social isolation condition could be validated within this experiment, which is consistent with previous research concerning perceived social isolation (Aron et al., 2005; J. T. Cacioppo & Cacioppo, 2018a; J. T. Cacioppo & Patrick, 2008; Dunbar & Shultz, 2007; Fliessbach et al., 2007; Inagaki et al., 2016; LeDoux, 2012; Rilling et al., 2002). It further shows that the manipulation of the experiment was successful and the individuals experienced a stronger wish for contact with others when socially isolated. The women showed a very quick adaptive thrive to affiliate which complies with the evolutionary perspective. It is also consistent with a stronger motivation for social behaviour to keep their social homeostasis when socially deprived (Matthews & Tye, 2019). Loneliness ratings did not show significant differences; therefore, feelings of loneliness did not appear so sudden and might explain the differences to previous research examining mainly loneliness. The strong desire for social contact was not induced by boredom since no differences in the boredom levels appeared between the two sessions. Further uncontrollability was equal throughout both conditions, so this was not a confounding variable either. Considering the significant impact of social isolation on social desire surprisingly no significant difference appeared in the desire levels for a phone or internet throughout the two sessions. The usage of the phone or internet would have given the opportunity to connect with friends or family but astonishingly the contact over a third medium might not have fulfilled the desire for human interactions.

Regarding a connection between social isolation and feelings of hunger and desire for food no impact was apparent between the conditions. The individuals did not significantly feel hungrier, nor wished for more food when socially deprived in contrast to animal studies (Schipper et al., 2018). In both conditions the participants received the same exact amount of food which corresponded to the calorie intake of an adult female, so a social deprived state of eight hours does not increase food related feelings. Maybe if the subjects would have had the chance to eat more especially addictive food like sweets a difference would appear within social isolation.

Also, contrarily to expectations no significant effect of the social deprivation on the three cognitive tasks measuring motor control, inhibition control and working memory, emerged. Even though animal studies did predict an impact of social isolation on these entities (Ouchi et al., 2013; Pereda-Perez et al., 2013; Shao et al., 2013) and human studies also showed correlations between loneliness and cognitive processes (Gow et al., 2007; Wilson et

al., 2007). One possible explanation is that the missing effects in the stress response reflect the obtained results of the cognitive task. Increased arousal and stress can increase the focus and attention, but since no significant physical changes were apparent no significant influence on the performance was visible. Nevertheless, slight differences after the isolation session did appear. The motoric function measured through finger tapping was slightly higher after the neutral condition but in both other tasks assessing the inhibition control and working memory the participant made less mistakes after the isolation session. This difference was more notable than the motoric results but still not significant. An idea for a missing effect in the performance between the two conditions might be that the participants used almost the same energy and resources over the day in both sessions which resulted in similar cognitive abilities. The individuals might also welcomed a cognitive challenge with greater motivation after both sessions since the experimental procedure could have been under stimulating.

In general, the results of mood, cortisol levels, heart rate and some other variables showed tendencies that stayed mostly in line with the presumption of studies focusing on perceived social isolation but did not reveal significant differences. Summing up a full sample might result in significant outcomes between the conditions. It is also imaginable that a longer isolation period is needed to lead to significant changes in mood, stress responses, physical arousal and cognitive processes. Finally, a variation of the manipulation variable is possible for example allowing interactions with affiliated persons, as real-life contact with related humans comprises an even stronger control situation. This leads to a stronger distinction between the social isolation and neutral condition and might reveals significant differences.

11.1. Limitations

The main limitation of the study comprises the incomplete sample size, leading to an underpowered study, making it very hard to detect a significant effect of the manipulated variable (social deprivation). Especially the sample used for the analysis of the cortisol level was very underpowered. Only half of the calculated sample in the power analysis could be included, therefore limiting the validity of the results. This fact might be the main reason why many results of previous studies strongly differed. In addition to that the inclusion criteria of women using hormonal contraceptives, in order to control for fluctuations in the hormonal cycle, lead to a lower probability of revealing a difference between the two conditions. As mentioned above, women using oral contraceptives show an attenuated cortisol response to stressors with almost no difference to the baseline compared to non-users and males (Kirschbaum, Pirke et al., 1995).

The extraordinary environmental circumstances surrounding the experimental period

might also have biased the obtained data. The COVID-19 pandemic collided with the testing of the participants. Considering that due to this situation most people needed to isolate for long periods and social interactions were restricted almost throughout the whole year 2020, it is possible that the subjects tested after February 2020 got habituated to social isolation.

Lastly some methodological restraints need to be mentioned. The model diagnostics were not fully accomplished which might have had an impact on the results even with a very robust model like the random intercepts and slopes model used for the analysis. Furthermore, some baseline values differed between the two sessions, which is not desired since an effect might not be entirely induced by the manipulation of the experiment. Another statistical limitation lies in the structure of the data. The random intercepts and slopes model deals with gradually rising or falling values, but a lot of variables showed fluctuating trajectories which makes the estimates of the model weaker. An improvement of the model to control for fluctuations might strengthen the precision of the estimates and raise the probability to obtain more accurate results.

11.2. Implications

This study added very important insight in understating the complex processes within humans, experiencing short-term social isolation. The results indicate that acute isolation does not immediately affect mood changes, cortisol levels or physical arousal. Moreover, no significant influence of the acute social isolation on cognitive processes or other motivational states like hunger could be validated. The main prominent finding is a sudden desire for social contact within a short-term social deprivation period. Indicating that humans might immediately react to countermeasure undesired circumstances and to prevent negative outcomes like negative mood, stress or health consequences resulting from them.

Considering the reduced sample size future studies should examine the acute forced social isolation over a period longer than eight hours, with more subjects. Furthermore, the sample should be variated and include males given that social support has different effects on cortisol levels and perceived stress between the sexes (Kirschbaum, Klauer et al., 1995). Also, in order to evaluate if a decreased sensitivity of cortisol (Kirschbaum, Pirke et al., 1995) is the reason for a missing effect of the social isolation condition, women without contraceptives should be examined. Lastly, different nuances of social interactions should be assessed as contact with related persons, may account for a stronger manipulation and difference between the two conditions. These adaptations on one hand could help clarify the contrasting results of this study to previous research; on the other it could clarify if humans are indeed able to be alone for a longer period without severe negative consequences compared to animals.

New developments like the current COVID-19 pandemic restrict people from meeting and interacting so further knowledge in this field can be very valuable. The prevention of social interactions might have long term effects in the future of a person. Considering the results of this study which imply that the desire for phone and internet is not significantly higher throughout social isolation even though a strong desire for interactions were apparent, the indirect contact over devices may not fulfil the need for affiliation in full extent. This finding is very important regarding the current possibilities in the pandemic, which mainly allow these kinds of interactions.

Summing up, humans inherit a biological imperative to connect with other people which is directly linked to their reward system. This system evolved over a long period of time and urges humans to affiliate soon after a very short period of social isolation as validated in this study. Future studies should focus on broader samples and a longer experimental period with different manipulations of the control condition to give further knowledge about this very crucial topic for humans.

12. References

Adam, E. K., Hawkley, L. C., Kudielka, B. M., & Cacioppo, J. T. (2006). Day-to-day dynamics of experience-cortisol associations in a population-based sample of older adults. *Proceedings of the National Academy of Sciences*, *103*(45), 17058–17063. https://doi.org/10.1073/pnas.0605053103

Aktories, K., Förstermann, U., Starke, K., & Hofmann, F., B. (Eds.). (2017). *Allgemeine und spezielle Pharmakologie und Toxikologie: Begründet von W. Forth, D. Henschler, W. Rummel*. Elsevier Health Sciences.

Alcaraz, K. I., Eddens, K. S., Blase, J. L., Diver, W. R., Patel, A. V., Teras, L. R., Stevens, V. L., Jacobs, E. J., & Gapstur, S. M. (2019). Social Isolation and Mortality in US Black and White Men and Women. *American Journal of Epidemiology*, *188*(1), 102–109. https://doi.org/10.1093/aje/kwy231

Alexander, B. K., Coambs, R. B., & Hadaway, P. F. (1978). The effect of housing and gender on morphine self-administration in rats. *Psychopharmacology*, *58*(2), 175–179. https://doi.org/10.1007/BF00426903

Anderson, L., & Shimamura, A. P. (2005). Influences of emotion on context memory while viewing film clips. *The American Journal of Psychology*, *118*(3), 323–337.

Angermeier, W. F. (1960). Some basic aspects of social reinforcements in albino rats. *Journal of Comparative and Physiological Psychology*, *53*(4), 364–367. https://doi.org/10.1037/h0047435

Aron, A., Fisher, H., Mashek, D. J., Strong, G., Li, H., & Brown, L. L. (2005). Reward, Motivation, and Emotion Systems Associated with Early-Stage Intense Romantic Love. *Journal of Neurophysiology*, *94*(1), 327–337. https://doi.org/10.1152/jn.00838.2004

Averill, J. R. (1973). Personal control over aversive stimuli and its relationship to stress. *Psychological Bulletin*, *80*(4), 286–303. https://doi.org/10.1037/h0034845

Baba, V. V., Jamal, M., & Tourigny, L. (1998). Work and mental health: A decade in Canadian research. *Canadian Psychology/Psychologie Canadienne*, *39*(1–2), 94–107. https://doi.org/10.1037/h0086798

Barrett, L. F., & Russell, J. A. (1999). The Structure of Current Affect: Controversies and Emerging Consensus. *Current Directions in Psychological Science*, *8*(1), 10–14. https://doi.org/10.1111/1467-8721.00003

Bartels, M., Cacioppo, J. T., Hudziak, J. J., & Boomsma, D. I. (2008). Genetic and environmental contributions to stability in loneliness throughout childhood. *American Journal of Medical Genetics. Part B, Neuropsychiatric Genetics: The Official Publication of*

the International Society of Psychiatric Genetics, *147*(3), 385–391. https://doi.org/10.1002/ajmg.b.30608

Baumeister, R. F., & Leary, M. R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin*, *117*(3), 497–529. https://doi.org/10.1037/0033-2909.117.3.497

Baumeister, R. F., Vohs, K. D., Nathan DeWall, C., & Liqing Zhang. (2007). How Emotion Shapes Behavior: Feedback, Anticipation, and Reflection, Rather Than Direct Causation. *Personality and Social Psychology Review*, *11*(2), 167–203. https://doi.org/10.1177/1088868307301033

Berg, R. L., & Cassells, J. S. (1992). Social Isolation Among Older Individuals: The Relationship to Mortality and Morbidity. In *The Second Fifty Years: Promoting Health and Preventing Disability*. National Academies Press (US). 10.17226/1578

Berridge, K. C., & Kringelbach, M. L. (2015). Pleasure systems in the brain. *Neuron*, *86*(3), 646–664. https://doi.org/10.1016/j.neuron.2015.02.018

Bodenmann, G., & Gmelch, S. (2009). Stressbewältigung. In J. Margraf & S. Schneider (Eds.), *Lehrbuch der Verhaltenstherapie* (pp. 617–629). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-79543-8_30

Boomsma, D. I., Willemsen, G., Dolan, C. V., Hawkley, L. C., & Cacioppo, J. T. (2005). Genetic and environmental contributions to loneliness in adults: The Netherlands twin register study. *Behavior Genetics*, *35*(6), 745–752. https://doi.org/10.1007/s10519-005-6040-8

Brown, R., & Kulik, J. (1977). Flashbulb memories. *Cognition*, *5*(1), 73–99. https://doi.org/10.1016/0010-0277(77)90018-X

Bzdok, D., & Dunbar, R. I. M. (2020). The Neurobiology of Social Distance. *Trends in Cognitive Sciences*, *24*(9), 717–733. https://doi.org/10.1016/j.tics.2020.05.016

Cacioppo, J., T. (2005). People thinking about people: The vicious cycle of being a social outcast in one's own mind. *The Social Outcast: Ostracism, Social Exclusion, Rejection, and Bullying*, 91–108.

Cacioppo, J. T., & Cacioppo, S. (2018a). Loneliness in the Modern Age: An Evolutionary Theory of Loneliness (ETL). In *Advances in Experimental Social Psychology* (Vol. 58, pp. 127–197). Elsevier. https://doi.org/10.1016/bs.aesp.2018.03.003

Cacioppo, J. T., & Cacioppo, S. (2018b). The growing problem of loneliness. *The Lancet*, *391*(10119), 426. https://doi.org/10.1016/S0140-6736(18)30142-9

Cacioppo, J. T., Chen, H. Y., & Cacioppo, S. (2017). Reciprocal Influences Between Loneliness and Self-Centeredness: A Cross-Lagged Panel Analysis in a Population-Based Sample of African American, Hispanic, and Caucasian Adults. *Personality & Social Psychology Bulletin*, *43*(8), 1125–1135. https://doi.org/10.1177/0146167217705120

Cacioppo, J. T., Ernst, J. M., Burleson, M. H., McClintock, M. K., Malarkey, W. B., Hawkley, L. C., Kowalewski, R. B., Paulsen, A., Hobson, J. A., Hugdahl, K., Spiegel, D., & Berntson, G. G. (2000). Lonely traits and concomitant physiological processes: The MacArthur social neuroscience studies. *International Journal of Psychophysiology: Official Journal of the International Organization of Psychophysiology*, *35*(2–3), 143–154. https://doi.org/10.1016/s0167-8760(99)00049-5

Cacioppo, J. T., & Hawkley, L. C. (2009). Perceived social isolation and cognition. *Trends in Cognitive Sciences*, *13*(10), 447–454. https://doi.org/10.1016/j.tics.2009.06.005

Cacioppo, J. T., Hawkley, L. C., Norman, G. J., & Berntson, G. G. (2011). Social isolation. *Annals of the New York Academy of Sciences*, *1231*(1), 17–22. https://doi.org/10.1111/j.1749-6632.2011.06028.x

Cacioppo, J. T., Hughes, M. E., Waite, L. J., Hawkley, L. C., & Thisted, R. A. (2006). Loneliness as a specific risk factor for depressive symptoms: Cross-sectional and longitudinal analyses. *Psychology and Aging*, *21*(1), 140–151. https://doi.org/10.1037/0882-7974.21.1.140

Cacioppo, J. T., & Patrick, W. (2009). *Loneliness: Human nature and the need for social connection*. W. W. Norton.

Cacioppo, S., Frum, C., Asp, E., Weiss, R. M., Lewis, J. W., & Cacioppo, J. T. (2013). A quantitative meta-analysis of functional imaging studies of social rejection. *Scientific Reports*, *3*, 2027. https://doi.org/10.1038/srep02027

Cannon, W., B. (1929). Organization for physiological homeostasis. *Physiological Reviews*, *9*(3), 399–431.

Cannon, W. B. (1927). The James-Lange theory of emotions: A critical examination and an alternative theory. *American Journal of Psychology*, *39*, 106–124.

Cannon, W., B. (1932). *The Wisdom of the Body*. W. W. Norton.

Carlson, M., Charlin, V., & Miller, N. (1988). Positive mood and helping behavior: A test of six hypotheses. *Journal of Personality and Social Psychology*, *55*(2), 211–229. https://doi.org/10.1037//0022-3514.55.2.211

Carone, D. A. (2007). E. Strauss, E. M. S. Sherman, & O. Spreen, *A Compendium of Neuropsychological Tests: Administration, Norms, and Commentary*: A Review of: "(3rd

ed.), Oxford University Press, New York, 2006." *Applied Neuropsychology*, *14*(1), 62–63. https://doi.org/10.1080/09084280701280502

Chen, Y., & Baram, T. Z. (2016). Toward Understanding How Early-Life Stress Reprograms Cognitive and Emotional Brain Networks. *Neuropsychopharmacology: Official Publication of the American College of Neuropsychopharmacology*, *41*(1), 197–206. https://doi.org/10.1038/npp.2015.181

Chrousos, G. P. (2009). Stress and disorders of the stress system. *Nature Reviews. Endocrinology*, *5*(7), 374–381. https://doi.org/10.1038/nrendo.2009.106

Clark, L. A., & Watson, D. (1988). Mood and the mundane: Relations between daily life events and self-reported mood. *Journal of Personality and Social Psychology*, *54*(2), 296–308. https://doi.org/10.1037//0022-3514.54.2.296

Clow, A., Hucklebridge, F., & Thorn, L. (2010). The cortisol awakening response in context. *International Review of Neurobiology*, *93*, 153–175. https://doi.org/10.1016/S0074-7742(10)93007-9

Cohen, J. (1977). *Statistical power analysis for the behavioral sciences* (Rev. ed). Academic Press.

Cole, Steve W. (2008). Social regulation of leukocyte homeostasis: The role of glucocorticoid sensitivity. *Brain, Behavior, and Immunity*, *22*(7), 1049–1055. https://doi.org/10.1016/j.bbi.2008.02.006

Cole, Steve W., Hawkley, L. C., Arevalo, J. M., Sung, C. Y., Rose, R. M., & Cacioppo, J. T. (2007). Social regulation of gene expression in human leukocytes. *Genome Biology*, *8*(9), R189. https://doi.org/10.1186/gb-2007-8-9-r189

Cole, Steven W., Capitanio, J. P., Chun, K., Arevalo, J. M. G., Ma, J., & Cacioppo, J. T. (2015). Myeloid differentiation architecture of leukocyte transcriptome dynamics in perceived social isolation. *Proceedings of the National Academy of Sciences of the United States of America*, *112*(49), 15142–15147. https://doi.org/10.1073/pnas.1514249112

Cornwell, E. Y., & Waite, L. J. (2009). Social disconnectedness, perceived isolation, and health among older adults. *Journal of Health and Social Behavior*, *50*(1), 31–48. https://doi.org/10.1177/002214650905000103

Coyle, C. E., & Dugan, E. (2012). Social isolation, loneliness and health among older adults. *Journal of Aging and Health*, *24*(8), 1346–1363. https://doi.org/10.1177/0898264312460275

Crockford, C., Wittig, R. M., Whitten, P. L., Seyfarth, R. M., & Cheney, D. L. (2008). Social stressors and coping mechanisms in wild female baboons (Papio hamadryas ursinus). *Hormones and Behavior*, *53*(1), 254–265. https://doi.org/10.1016/j.yhbeh.2007.10.007

Cruwys, T., Dingle, G. A., Haslam, C., Haslam, S. A., Jetten, J., & Morton, T. A. (2013). Social group memberships protect against future depression, alleviate depression symptoms and prevent depression relapse. *Social Science & Medicine (1982)*, *98*, 179–186. https://doi.org/10.1016/j.socscimed.2013.09.013

Cunningham, M. R. (1988a). Does Happiness Mean Friendliness?: Induced Mood and Heterosexual Self-Disclosure. *Personality & Social Psychology Bulletin*, *14*(2), 283–297. https://doi.org/10.1177/0146167288142007

Cunningham, M. R. (1988b). What do you do when you're happy or blue? Mood, expectancies, and behavioral interest. *Motivation and Emotion*, *12*(4), 309–331. https://doi.org/10.1007/BF00992357

Dahlbert, C. (1992). Subjektives Wohlbefinden junger Erwachsener: Theoretische und empirische Analysen der Struktur und Stabilität [Young adults' subjective well-being: Theoretical and empirical analyses of its structure and stability]. *Zeitschrift Für Differentielle Und Diagnostische Psychologie*, *13*(4), 207–220.

Davidson, R. J., Scherer, K. R., & Goldsmith, H. H. (Eds.). (2003). *Handbook of affective sciences*. Oxford University Press.

Dias-Ferreira, E., Sousa, J. C., Melo, I., Morgado, P., Mesquita, A. R., Cerqueira, J. J., Costa, R. M., & Sousa, N. (2009). Chronic stress causes frontostriatal reorganization and affects decision-making. *Science (New York, N.Y.)*, *325*(5940), 621–625. https://doi.org/10.1126/science.1171203

Dickerson, S. S., Gruenewald, T. L., & Kemeny, M. E. (2004). When the social self is threatened: Shame, physiology, and health. *Journal of Personality*, *72*(6), 1191–1216. https://doi.org/10.1111/j.1467-6494.2004.00295.x

Dickerson, S. S., Gruenewald, T. L., & Kemeny, M. E. (2009). Psychobiological Responses to Social Self Threat: Functional or Detrimental? *Self and Identity*, *8*(2–3), 270–285. https://doi.org/10.1080/15298860802505186

Dickerson, S. S., & Kemeny, M. E. (2004). Acute stressors and cortisol responses: A theoretical integration and synthesis of laboratory research. *Psychological Bulletin*, *130*(3), 355–391. https://doi.org/10.1037/0033-2909.130.3.355

Doane, L. D., & Adam, E. K. (2010). Loneliness and cortisol: Momentary, day-to-day, and trait associations. *Psychoneuroendocrinology*, *35*(3), 430–441. https://doi.org/10.1016/j.psyneuen.2009.08.005

Dohrenwend, B. S., & Dohrenwend, B. P. (1974). *Stressful life events: Their nature and effects*. John Wiley & Sons.

Dronjak, S., Gavrilovi, L., Filipovi, D., & Radoji, M. (2004). Immobilization and cold stress affect sympatho–adrenomedullary system and pituitary–adrenocortical axis of rats exposed to long-term isolation and crowding. *Physiology & Behavior*, *81*(3), 409–415. https://doi.org/10.1016/j.physbeh.2004.01.011

Duffy, E. (1957). The psychological significance of the concept of arousal or activation. *Psychological Review*, *64*(5), 265–275. https://doi.org/10.1037/h0048837

Dunbar, R. I. M., & Shultz, S. (2007). Evolution in the Social Brain. *Science*, *317*(5843), 1344–1347. https://doi.org/10.1126/science.1145463

Dunbar, R. I. M. (2016). The Social Brain Hypothesis and Human Evolution. In Robin I. M. Dunbar, *Oxford Research Encyclopedia of Psychology*. Oxford University Press. https://doi.org/10.1093/acrefore/9780190236557.013.44

Dykstra, P. A., & Fokkema, T. (2007). Social and Emotional Loneliness Among Divorced and Married Men and Women: Comparing the Deficit and Cognitive Perspectives. *Basic and Applied Social Psychology*, *29*(1), 1–12. https://doi.org/10.1080/01973530701330843

Edery-Halpern, G., & Nachson, I. (2004). Distinctiveness in flashbulb memory: Comparative analysis of five terrorist attacks. *Memory (Hove, England)*, *12*(2), 147–157. https://doi.org/10.1080/09658210244000432

Eisenberger, N. I. (2012). The pain of social disconnection: Examining the shared neural underpinnings of physical and social pain. *Nature Reviews Neuroscience*, *13*(6), 421–434. https://doi.org/10.1038/nrn3231

Eisenberger, N. I. (2015). Social pain and the brain: Controversies, questions, and where to go from here. *Annual Review of Psychology*, *66*, 601–629. https://doi.org/10.1146/annurev-psych-010213-115146

Eisenberger, N. I., Lieberman, M. D., & Williams, K. D. (2003). Does rejection hurt? An FMRI study of social exclusion. *Science (New York, N.Y.)*, *302*(5643), 290–292. https://doi.org/10.1126/science.1089134

Elder, G. J., Wetherell, M. A., Barclay, N. L., & Ellis, J. G. (2014). The cortisol awakening response—Applications and implications for sleep medicine. *Sleep Medicine Reviews*, *18*(3), 215–224. https://doi.org/10.1016/j.smrv.2013.05.001

Elwert, F., & Christakis, N. A. (2008). The effect of widowhood on mortality by the causes of death of both spouses. *American Journal of Public Health*, *98*(11), 2092–2098. https://doi.org/10.2105/AJPH.2007.114348

Engh, A. L., Beehner, J. C., Bergman, T. J., Whitten, P. L., Hoffmeier, R. R., Seyfarth, R. M., & Cheney, D. L. (2006). Behavioural and hormonal responses to predation in female chacma baboons (Papio hamadryas ursinus). *Proceedings. Biological Sciences*, *273*(1587), 707–712. https://doi.org/10.1098/rspb.2005.3378

Evans, D. R., Boggero, I. A., & Segerstrom, S. C. (2016). The Nature of Self-Regulatory Fatigue and "Ego Depletion": Lessons From Physical Fatigue. *Personality and Social Psychology Review: An Official Journal of the Society for Personality and Social Psychology, Inc*, *20*(4), 291–310. https://doi.org/10.1177/1088868315597841

Evans, M. J., Duvel, A., Funk, M. L., Lehman, B., Sparrow, J., Watson, N. T., & Neuringer, A. (1994). Social reinforcement of operant behavior in rats: A methodological note. *Journal of the Experimental Analysis of Behavior*, *62*(1), 149–156. https://doi.org/10.1901/jeab.1994.62-149

Filipović, D., Todorović, N., Bernardi, R. E., & Gass, P. (2017). Oxidative and nitrosative stress pathways in the brain of socially isolated adult male rats demonstrating depressive- and anxiety-like symptoms. *Brain Structure & Function*, *222*(1), 1–20. https://doi.org/10.1007/s00429-016-1218-9

Fink, G. (2016). Stress, Definitions, Mechanisms, and Effects Outlined. In *Stress: Concepts, Cognition, Emotion, and Behavior* (pp. 3–11). Elsevier. https://doi.org/10.1016/B978-0-12-800951-2.00001-7

Fliessbach, K., Weber, B., Trautner, P., Dohmen, T., Sunde, U., Elger, C. E., & Falk, A. (2007). Social comparison affects reward-related brain activity in the human ventral striatum. *Science (New York, N.Y.)*, *318*(5854), 1305–1308. https://doi.org/10.1126/science.1145876

Folkman, S., & Moskowitz, J. T. (2004). Coping: Pitfalls and promise. *Annual Review of Psychology*, *55*, 745–774. https://doi.org/10.1146/annurev.psych.55.090902.141456

Fonagy, P., & Target, M. (2005). Bridging the transmission gap: An end to an important mystery of attachment research? *Attachment & Human Development*, *7*(3), 333–343. https://doi.org/10.1080/14616730500269278

Francis, R. D. (1969). Introversion and Isolation Tolerance. *Perceptual and Motor Skills*, *28*(2), 534–534. https://doi.org/10.2466/pms.1969.28.2.534

Gable, S. L. (2006). Approach and avoidance social motives and goals. *Journal of Personality*, *74*(1), 175–222. https://doi.org/10.1111/j.1467-6494.2005.00373.x

Gamman, T. (2001). Om bruk av isolasjon under varetektsfengsling. *Nordisk Tidsskrift for Kriminalvidenskab*, *88*, 42–50.

Ghasemi, M., & Dehpour, A. R. (2009). Ethical considerations in animal studies. *Journal of Medical Ethics and History of Medicine*, *2*, 12.

Gilbert, P. (1997). The evolution of social attractiveness and its role in shame, humiliation, guilt and therapy. *The British Journal of Medical Psychology*, *70 (Pt 2)*, 113–147. https://doi.org/10.1111/j.2044-8341.1997.tb01893.x

Gow, A. J., Pattie, A., Whiteman, M. C., Whalley, L. J., & Deary, I. J. (2007). Social Support and Successful Aging: Investigating the Relationships Between Lifetime Cognitive Change and Life Satisfaction. *Journal of Individual Differences*, *28*(3), 103–115. https://doi.org/10.1027/1614-0001.28.3.103

Grant, N., Hamer, M., & Steptoe, A. (2009). Social isolation and stress-related cardiovascular, lipid, and cortisol responses. *Annals of Behavioral Medicine: A Publication of the Society of Behavioral Medicine*, *37*(1), 29–37. https://doi.org/10.1007/s12160-009-9081-z

Gray, J. R., Braver, T. S., & Raichle, M. E. (2002). Integration of emotion and cognition in the lateral prefrontal cortex. *Proceedings of the National Academy of Sciences of the United States of America*, *99*(6), 4115–4120. https://doi.org/10.1073/pnas.062381899

Grippo, A. J., Lamb, D. G., Carter, C. S., & Porges, S. W. (2007). Social isolation disrupts autonomic regulation of the heart and influences negative affective behaviors. *Biological Psychiatry*, *62*(10), 1162–1170. https://doi.org/10.1016/j.biopsych.2007.04.011

Haber, S. N., & Knutson, B. (2010). The reward circuit: Linking primate anatomy and human imaging. *Neuropsychopharmacology: Official Publication of the American College of Neuropsychopharmacology*, *35*(1), 4–26. https://doi.org/10.1038/npp.2009.129

Hall, F. S. (1998). Social deprivation of neonatal, adolescent, and adult rats has distinct neurochemical and behavioral consequences. *Critical Reviews in Neurobiology*, *12*(1–2), 129–162. https://doi.org/10.1615/critrevneurobiol.v12.i1-2.50

Haney, C. (2003). The psychological impact of incarceration: Implications for post-prison adjustment. *Prisoners Once Removed: The Impact of Incarceration and Reentry on Children, Families, and Communities*, 33–66.

Harlow, H., F. (1958). The nature of love. *American Psychologist*, *13*(12), 673.

Harlow, H. F., Dodsworth, R. O., & Harlow, M. K. (1965). Total social isolation in monkeys. *Proceedings of the National Academy of Sciences*, *54*(1), 90–97. https://doi.org/10.1073/pnas.54.1.90

Hawkley, L. C., & Cacioppo, J. T. (2003). Loneliness and pathways to disease. *Brain, Behavior, and Immunity*, *17 Suppl 1*, S98-105. https://doi.org/10.1016/s0889-1591(02)00073-9

Hawkley, L. C., Cole, S. W., Capitanio, J. P., Norman, G. J., & Cacioppo, J. T. (2012). Effects of social isolation on glucocorticoid regulation in social mammals. *Hormones and Behavior*, *62*(3), 314–323. https://doi.org/10.1016/j.yhbeh.2012.05.011

Hawkley, L. C., Hughes, M. E., Waite, L. J., Masi, C. M., Thisted, R. A., & Cacioppo, J. T. (2008). From social structural factors to perceptions of relationship quality and loneliness: The Chicago health, aging, and social relations study. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences*, *63*(6), S375-384. https://doi.org/10.1093/geronb/63.6.s375

Hawkley, L. C., Thisted, R. A., & Cacioppo, J. T. (2009). Loneliness predicts reduced physical activity: Cross-sectional & longitudinal analyses. *Health Psychology: Official Journal of the Division of Health Psychology, American Psychological Association*, *28*(3), 354–363. https://doi.org/10.1037/a0014400

Heller, A. S., van Reekum, C. M., Schaefer, S. M., Lapate, R. C., Radler, B. T., Ryff, C. D., & Davidson, R. J. (2013). Sustained striatal activity predicts eudaimonic well-being and cortisol output. *Psychological Science*, *24*(11), 2191–2200. https://doi.org/10.1177/0956797613490744

Herrmann, E., Call, J., Hernàndez-Lloreda, M. V., Hare, B., & Tomasello, M. (2007). Humans have evolved specialized skills of social cognition: The cultural intelligence hypothesis. *Science (New York, N.Y.)*, *317*(5843), 1360–1366. https://doi.org/10.1126/science.1146282

Hinz, A., Daig, I., Petrowski, K., & Brähler, E. (2012). Die Stimmung in der deutschen Bevölkerung: Referenzwerte für den Mehrdimensionalen Befindlichkeitsfragebogen MDBF. *PPmP - Psychotherapie · Psychosomatik · Medizinische Psychologie*, *62*(02), 52–57. https://doi.org/10.1055/s-0031-1297960

Hiura, L. C., Tan, L., & Hackenberg, T. D. (2018). To free, or not to free: Social reinforcement effects in the social release paradigm with rats. *Behavioural Processes*, *152*, 37–46. https://doi.org/10.1016/j.beproc.2018.03.014

Holt-Lunstad, J., Smith, T. B., Baker, M., Harris, T., & Stephenson, D. (2015). Loneliness and social isolation as risk factors for mortality: A meta-analytic review. *Perspectives on Psychological Science: A Journal of the Association for Psychological Science*, *10*(2), 227–237. https://doi.org/10.1177/1745691614568352

Holt-Lunstad, J., Smith, T. B., & Layton, J. B. (2010). Social relationships and mortality risk: A meta-analytic review. *PLoS Medicine*, *7*(7), e1000316. https://doi.org/10.1371/journal.pmed.1000316

Huang, H., Liu, Y., & Liu, X. (2016). Does Loneliness Necessarily Lead to a Decrease in Pro-social Behavior? The Roles of Gender and Situation. *Frontiers in Psychology*, *7*, 1388. https://doi.org/10.3389/fpsyg.2016.01388

Huppelsberg, J., Walter, K., Gusta, M., & Gusta, P. (2009). *Kurzlehrbuch Physiologie: 42 Tabellen* (3., überarbeitete Auflage). Georg Thieme Verlag.

Inagaki, T. K., Muscatell, K. A., Moieni, M., Dutcher, J. M., Jevtic, I., Irwin, M. R., & Eisenberger, N. I. (2016). Yearning for connection? Loneliness is associated with increased ventral striatum activity to close others. *Social Cognitive and Affective Neuroscience*, *11*(7), 1096–1101. https://doi.org/10.1093/scan/nsv076

Iversen, S., Kupfermann, I., & Kandel, E. R. (2000). Emotional states and feelings. *Principles of Neural Science*, *4*, 982–997.

Jaeggi, S. M., Buschkuehl, M., Perrig, W. J., & Meier, B. (2010). The concurrent validity of the *N* -back task as a working memory measure. *Memory*, *18*(4), 394–412. https://doi.org/10.1080/09658211003702171

James, W. (1884). What is an emotion? *Mind*, *9*(34), 188–205.

Joëls, M., Hesen, W., & de Kloet, E. R. (1991). Mineralocorticoid hormones suppress serotonin-induced hyperpolarization of rat hippocampal CA1 neurons. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, *11*(8), 2288–2294.

Juster, R.-P., McEwen, B. S., & Lupien, S. J. (2010). Allostatic load biomarkers of chronic stress and impact on health and cognition. *Neuroscience and Biobehavioral Reviews*, *35*(1), 2–16. https://doi.org/10.1016/j.neubiorev.2009.10.002

Kanitz, E., Tuchscherer, M., Puppe, B., Tuchscherer, A., & Stabenow, B. (2004). Consequences of repeated early isolation in domestic piglets (Sus scrofa) on their behavioural, neuroendocrine, and immunological responses. *Brain, Behavior, and Immunity*, *18*(1), 35–45. https://doi.org/10.1016/s0889-1591(03)00085-0

Karelina, K., Norman, G. J., Zhang, N., Morris, J. S., Peng, H., & DeVries, A. C. (2009). Social isolation alters neuroinflammatory response to stroke. *Proceedings of the National Academy of Sciences*, *106*(14), 5895–5900. https://doi.org/10.1073/pnas.0810737106

Karpova, I. V., Mikheev, V. V., Marysheva, V. V., Bychkov, E. R., & Proshin, S. N. (2016). Oxytocin-Induced Changes in Monoamine Level in Symmetric Brain Structures of Isolated Aggressive C57Bl/6 Mice. *Bulletin of Experimental Biology and Medicine*, *160*(5), 605–609. https://doi.org/10.1007/s10517-016-3228-2

Kertzman, S., Lidogoster, H., Aizer, A., Kotler, M., & Dannon, P. N. (2011). Risk-taking decisions in pathological gamblers is not a result of their impaired inhibition ability. *Psychiatry Research*, *188*(1), 71–77. https://doi.org/10.1016/j.psychres.2011.02.021

Kim, J. J., & Diamond, D. M. (2002). The stressed hippocampus, synaptic plasticity and lost memories. *Nature Reviews. Neuroscience*, *3*(6), 453–462. https://doi.org/10.1038/nrn849

Kirschbaum, C., Klauer, T., Filipp, S. H., & Hellhammer, D. H. (1995a). Sex-specific effects of social support on cortisol and subjective responses to acute psychological stress. *Psychosomatic Medicine*, *57*(1), 23–31. https://doi.org/10.1097/00006842-199501000-00004

Kirschbaum, C., Pirke, K. M., & Hellhammer, D. H. (1995b). Preliminary evidence for reduced cortisol responsivity to psychological stress in women using oral contraceptive medication. *Psychoneuroendocrinology*, *20*(5), 509–514. https://doi.org/10.1016/0306-4530(94)00078-o

Kirschbaum, C., Prüssner, J. C., Stone, A. A., Federenko, I., Gaab, J., Lintz, D., Schommer, N., & Hellhammer, D. H. (1995c). Persistent high cortisol responses to repeated psychological stress in a subpopulation of healthy men. *Psychosomatic Medicine*, *57*(5), 468–474. https://doi.org/10.1097/00006842-199509000-00009

Klawonn, A. M., & Malenka, R. C. (2018). Nucleus Accumbens Modulation in Reward and Aversion. *Cold Spring Harbor Symposia on Quantitative Biology*, *83*, 119–129. https://doi.org/10.1101/sqb.2018.83.037457

Klinke, R., Pape, H.-C., Kurtz, A., Silbernagl, S., Baumann, R., Brenner, B., Gay, R., & Rothenburger, A. (Eds.). (2010). *Physiologie* (6., vollst. überarb. Aufl). Thieme.

Klüver, H., & Bucy, P. C. (1997). Preliminary analysis of functions of the temporal lobes in monkeys. 1939. *The Journal of Neuropsychiatry and Clinical Neurosciences*, *9*(4), 606–620. https://doi.org/10.1176/jnp.9.4.606

Knoll, N., Scholz, U., Rieckmann, N., & Schwarzer, R. (2017). *Einführung Gesundheitspsychologie* (4., aktualisierte Auflage). Ernst Reinhardt Verlag.

Kogler, L., Müller, V. I., Chang, A., Eickhoff, S. B., Fox, P. T., Gur, R. C., & Derntl, B. (2015). Psychosocial versus physiological stress—Meta-analyses on deactivations and activations of the neural correlates of stress reactions. *NeuroImage*, *119*, 235–251. https://doi.org/10.1016/j.neuroimage.2015.06.059

Kong, X., Wei, D., Li, W., Cun, L., Xue, S., Zhang, Q., & Qiu, J. (2015). Neuroticism and extraversion mediate the association between loneliness and the dorsolateral prefrontal cortex. *Experimental Brain Research*, *233*(1), 157–164. https://doi.org/10.1007/s00221-014-4097-4

Kraut, R. E., & Johnston, R. E. (1979). Social and emotional messages of smiling: An ethological approach. *Journal of Personality and Social Psychology*, *37*(9), 1539–1553. https://doi.org/10.1037/0022-3514.37.9.1539

Kross, E., Berman, M. G., Mischel, W., Smith, E. E., & Wager, T. D. (2011). Social rejection shares somatosensory representations with physical pain. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(15), 6270–6275. https://doi.org/10.1073/pnas.1102693108

Kudielka, B. M., Hellhammer, D. H., & Wüst, S. (2009). Why do we respond so differently? Reviewing determinants of human salivary cortisol responses to challenge. *Psychoneuroendocrinology*, *34*(1), 2–18. https://doi.org/10.1016/j.psyneuen.2008.10.004

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2017). **lmerTest** Package: Tests in Linear Mixed Effects Models. *Journal of Statistical Software*, *82*(13). https://doi.org/10.18637/jss.v082.i13

Lallai, V., Manca, L., & Dazzi, L. (2016). Social Isolation Blunted the Response of Mesocortical Dopaminergic Neurons to Chronic Ethanol Voluntary Intake. *Frontiers in Cellular Neuroscience*, *10*, 155. https://doi.org/10.3389/fncel.2016.00155

Layden, E. A., Cacioppo, J. T., & Cacioppo, S. (2018). Loneliness predicts a preference for larger interpersonal distance within intimate space. *PloS One*, *13*(9), e0203491. https://doi.org/10.1371/journal.pone.0203491

Lazarus, R., S. (1982). Thoughts on the relations between emotion and cognition. *American Psychologist*, *37*, 1019–1024.

Lazarus, R. S., & Folkman, S. (1999). *Stress, appraisal, and coping*. Springer. http://www.dawsonera.com/depp/reader/protected/external/AbstractView/S9780826141927

LeDoux, Joseph. (2012). Rethinking the Emotional Brain. *Neuron*, *73*(4), 653–676. https://doi.org/10.1016/j.neuron.2012.02.004

Leigh-Hunt, N., Bagguley, D., Bash, K., Turner, V., Turnbull, S., Valtorta, N., & Caan, W. (2017). An overview of systematic reviews on the public health consequences of social isolation and loneliness. *Public Health*, *152*, 157–171. https://doi.org/10.1016/j.puhe.2017.07.035

Levine, L. J., & Edelstein, R. S. (2009). Emotion and memory narrowing: A review and goal-relevance approach. *Cognition & Emotion*, *23*(5), 833–875. https://doi.org/10.1080/02699930902738863

Levine, S., & Ursin, H. (1991). What is stress? In M. Brown R., G. Koob F., & C. Rivier (Eds.), *Stress, neurobiology and neuroendocrinology* (pp. 3–21). Dekker.

Lewis, M. D. (2005). Bridging emotion theory and neurobiology through dynamic systems modeling. *The Behavioral and Brain Sciences*, *28*(2), 169–194; discussion 194-245. https://doi.org/10.1017/s0140525x0500004x

Leyton, M. (2007). Conditioned and sensitized responses to stimulant drugs in humans. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, *31*(8), 1601–1613. https://doi.org/10.1016/j.pnpbp.2007.08.027

Loseth, G. E., Ellingsen, D.-M., & Leknes, S. (2014). State-dependent μ-opioid modulation of social motivation. *Frontiers in Behavioral Neuroscience*, *8*. https://doi.org/10.3389/fnbeh.2014.00430

Lovallo, W. R., Pincomb, G. A., Brackett, D. J., & Wilson, M. F. (1990). Heart rate reactivity as a predictor of neuroendocrine responses to aversive and appetitive challenges. *Psychosomatic Medicine*, *52*(1), 17–26. https://doi.org/10.1097/00006842-199001000-00002

Matsumoto, K., Pinna, G., Puia, G., Guidotti, A., & Costa, E. (2005). Social isolation stress-induced aggression in mice: A model to study the pharmacology of neurosteroidogenesis. *Stress (Amsterdam, Netherlands)*, *8*(2), 85–93. https://doi.org/10.1080/10253890500159022

Matthews, G. A., Nieh, E. H., Vander Weele, C. M., Halbert, S. A., Pradhan, R. V., Yosafat, A. S., Glober, G. F., Izadmehr, E. M., Thomas, R. E., Lacy, G. D., Wildes, C. P., Ungless, M. A., & Tye, K. M. (2016). Dorsal Raphe Dopamine Neurons Represent the Experience of Social Isolation. *Cell*, *164*(4), 617–631. https://doi.org/10.1016/j.cell.2015.12.040

Matthews, G. A., & Tye, K. M. (2019). Neural mechanisms of social homeostasis. *Annals of the New York Academy of Sciences*, *1457*(1), 5–25. https://doi.org/10.1111/nyas.14016

McEwen, B. S., & Stellar, E. (1993). Stress and the individual. Mechanisms leading to disease. *Archives of Internal Medicine*, *153*(18), 2093–2101.

McIntyre, C. W., Watson, D., Clark, L. A., & Cross, S. A. (1991). The effect of induced social interaction on positive and negative affect. *Bulletin of the Psychonomic Society*, *29*(1), 67–70. https://doi.org/10.3758/BF03334773

McIntyre, C. W., Watson, D., & Cunningham, A. C. (1990). The effects of social interaction, exercise, and test stress on positive and negative affect. *Bulletin of the Psychonomic Society*, *28*(2), 141–143. https://doi.org/10.3758/BF03333988

Meule, A. (2017). Reporting and Interpreting Task Performance in Go/No-Go Affective Shifting Tasks. *Frontiers in Psychology*, *8*, 701. https://doi.org/10.3389/fpsyg.2017.00701

Miyawaki, C. E. (2015). Association of social isolation and health across different racial and ethnic groups of older Americans. *Ageing and Society*, *35*(10), 2201–2228. https://doi.org/10.1017/S0144686X14000890

Mumtaz, F., Khan, M. I., Zubair, M., & Dehpour, A. R. (2018). Neurobiology and consequences of social isolation stress in animal model-A comprehensive review. *Biomedicine & Pharmacotherapy = Biomedecine & Pharmacotherapie*, *105*, 1205–1222. https://doi.org/10.1016/j.biopha.2018.05.086

Nation, D. A., Gonzales, J. A., Mendez, A. J., Zaias, J., Szeto, A., Brooks, L. G., Paredes, J., D'Angola, A., Schneiderman, N., & McCabe, P. M. (2008). The Effect of Social Environment on Markers of Vascular Oxidative Stress and Inflammation in the Watanabe Heritable Hyperlipidemic Rabbit: *Psychosomatic Medicine*, *70*(3), 269–275. https://doi.org/10.1097/PSY.0b013e3181646753

Nestor, L., McCabe, E., Jones, J., Clancy, L., & Garavan, H. (2011). Differences in "bottom-up" and "top-down" neural activity in current and former cigarette smokers: Evidence for neural substrates which may promote nicotine abstinence through increased cognitive control. *NeuroImage*, *56*(4), 2258–2275. https://doi.org/10.1016/j.neuroimage.2011.03.054

Netter, P., & Hennig, J. (2002). Stress, biopsychologische Perspektive. In *Gesundheitspsychologie von A bis Z*. Hogrefe.

Newsom, J. T., Nishishiba, M., Morgan, D. L., & Rook, K. S. (2003). The relative importance of three domains of positive and negative social exchanges: A longitudinal model with

comparable measures. *Psychology and Aging*, *18*(4), 746–754. https://doi.org/10.1037/0882-7974.18.4.746

Niesink, R. J., & van Ree, J. M. (1982). Short-term isolation increases social interactions of male rats: A parametric analysis. *Physiology & Behavior*, *29*(5), 819–825. https://doi.org/10.1016/0031-9384(82)90331-6

Nonogaki, K., Nozue, K., & Oka, Y. (2007). Social isolation affects the development of obesity and type 2 diabetes in mice. *Endocrinology*, *148*(10), 4658–4666. https://doi.org/10.1210/en.2007-0296

O'Doherty, J. P. (2004). Reward representations and reward-related learning in the human brain: Insights from neuroimaging. *Current Opinion in Neurobiology*, *14*(6), 769–776. https://doi.org/10.1016/j.conb.2004.10.016

Ouchi, H., Ono, K., Murakami, Y., & Matsumoto, K. (2013). Social isolation induces deficit of latent learning performance in mice: A putative animal model of attention deficit/hyperactivity disorder. *Behavioural Brain Research*, *238*, 146–153. https://doi.org/10.1016/j.bbr.2012.10.029

Panksepp, J., & Beatty, W. W. (1980). Social deprivation and play in rats. *Behavioral and Neural Biology*, *30*(2), 197–206. https://doi.org/10.1016/s0163-1047(80)91077-8

Papez, J. W. (1995). A proposed mechanism of emotion. 1937. *The Journal of Neuropsychiatry and Clinical Neurosciences*, *7*(1), 103–112. https://doi.org/10.1176/jnp.7.1.103

Parija, S. & Shukla, A. (2014). Behavior of People: Role of Extraversion and Loneliness. *Psychology and Behavioral Sciences*, *3*(1), 17. https://doi.org/10.11648/j.pbs.20140301.14

Pereda-Pérez, I., Popović, N., Otalora, B. B., Popović, M., Madrid, J. A., Rol, M. A., & Venero, C. (2013). Long-term social isolation in the adulthood results in CA1 shrinkage and cognitive impairment. *Neurobiology of Learning and Memory*, *106*, 31–39. https://doi.org/10.1016/j.nlm.2013.07.004

Pessoa, L. (2008). On the relationship between emotion and cognition. *Nature Reviews. Neuroscience*, *9*(2), 148–158. https://doi.org/10.1038/nrn2317

Pinquart, M., & Duberstein, P. R. (2010). Associations of social networks with cancer mortality: A meta-analysis. *Critical Reviews in Oncology/Hematology*, *75*(2), 122–137. https://doi.org/10.1016/j.critrevonc.2009.06.003

Poletto, R., Steibel, J. P., Siegford, J. M., & Zanella, A. J. (2006). Effects of early weaning and social isolation on the expression of glucocorticoid and mineralocorticoid receptor and 11beta-hydroxysteroid dehydrogenase 1 and 2 mRNAs in the frontal cortex and

hippocampus of piglets. *Brain Research*, *1067*(1), 36–42. https://doi.org/10.1016/j.brainres.2005.10.001

R Core Team. (2019). R: A language and environment for statistical computing. *R Foundation for Statistical Computing*. http://www.r-project.org/

Raz, S., & Berger, B. D. (2010). Social isolation increases morphine intake: Behavioral and psychopharmacological aspects. *Behavioural Pharmacology*, *21*(1), 39–46. https://doi.org/10.1097/FBP.0b013e32833470bd

Reblin, M., & Uchino, B. N. (2008). Social and emotional support and its implication for health. *Current Opinion in Psychiatry*, *21*(2), 201–205. https://doi.org/10.1097/YCO.0b013e3282f3ad89

Rhodes, L. A. (2004). *Total confinement: Madness and reason in the maximum security prison*. University of California Press.

Rilling, J., Gutman, D., Zeh, T., Pagnoni, G., Berns, G., & Kilts, C. (2002). A neural basis for social cooperation. *Neuron*, *35*(2), 395–405. https://doi.org/10.1016/s0896-6273(02)00755-9

Romero-Canyas, R., & Downey, G. (2005). Rejection sensitivity as a predictor of affective and behavioral responses to interpersonal stress. *The Social Outcast: Ostracism, Social Exclusion, Rejection, and Bullying*, 131–154.

Rook, K. S. (2001). Emotional Health and Positive Versus Negative Social Exchanges: A Daily Diary Analysis. *Applied Developmental Science*, *5*(2), 86–97. https://doi.org/10.1207/S1532480XADS0502_4

Rothermund, K., & Eder, A. (2011). *Allgemeine Psychologie: Motivation und Emotion*. VS Verlag für Sozialwissenschaften. https://doi.org/10.1007/978-3-531-93420-4

Ruan, H., & Wu, C.-F. (2008). Social interaction-mediated lifespan extension of Drosophila Cu/Zn superoxide dismutase mutants. *Proceedings of the National Academy of Sciences*, *105*(21), 7506–7510. https://doi.org/10.1073/pnas.0711127105

Ruiz, J. I. (2007). Emotional Climate in Organizations: Applications in Latin American Prisons. *Journal of Social Issues*, *63*(2), 289–306. https://doi.org/10.1111/j.1540-4560.2007.00509.x

Russell, D. W. (1996). UCLA Loneliness Scale (Version 3): Reliability, validity, and factor structure. *Journal of Personality Assessment*, *66*(1), 20–40. https://doi.org/10.1207/s15327752jpa6601_2

Saklofske, D. H., & Yackulic, R. A. (1989). Personality predictors of loneliness. *Personality and Individual Differences*, *10*(4), 467–472. https://doi.org/10.1016/0191-8869(89)90011-1

Schachter, S., & Singer, J. (1962). Cognitive, social, and physiological determinants of emotional state. *Psychological Review*, *69*(5), 379–399. https://doi.org/10.1037/h0046234

Schielzeth, H., Dingemanse, N. J., Nakagawa, S., Westneat, D. F., Allegue, H., Teplitsky, C., Réale, D., Dochtermann, N. A., Garamszegi, L. Z., & Araya-Ajoy, Y. G. (2020). Robustness of linear mixed-effects models to violations of distributional assumptions. *Methods in Ecology and Evolution*, *11*(9), 1141–1152. https://doi.org/10.1111/2041-210X.13434

Schipper, L., Harvey, L., van der Beek, E. M., & van Dijk, G. (2018). Home alone: A systematic review and meta-analysis on the effects of individual housing on body weight, food intake and visceral fat mass in rodents: Individual housing affects metabolic health. *Obesity Reviews*, *19*(5), 614–637. https://doi.org/10.1111/obr.12663

Schrijver, N. C. A., Pallier, P. N., Brown, V. J., & Würbel, H. (2004). Double dissociation of social and environmental stimulation on spatial learning and reversal learning in rats. *Behavioural Brain Research*, *152*(2), 307–314. https://doi.org/10.1016/j.bbr.2003.10.016

Schwabe, L., & Wolf, O. T. (2013). Stress and multiple memory systems: From "thinking" to "doing." *Trends in Cognitive Sciences*, *17*(2), 60–68. https://doi.org/10.1016/j.tics.2012.12.001

Schwarz, N., & Clore, G. L. (1983). Mood, misattribution, and judgments of well-being: Informative and directive functions of affective states. *Journal of Personality and Social Psychology*, *45*(3), 513–523. https://doi.org/10.1037/0022-3514.45.3.513

Selye, H. (1976). Stress without Distress. In G. Serban (Ed.), *Psychopathology of Human Adaptation* (pp. 137–146). Springer US. https://doi.org/10.1007/978-1-4684-2238-2_9

Seymour, B., Daw, N., Dayan, P., Singer, T., & Dolan, R. (2007). Differential Encoding of Losses and Gains in the Human Striatum. *Journal of Neuroscience*, *27*(18), 4826–4831. https://doi.org/10.1523/JNEUROSCI.0400-07.2007

Shaffer, F., & Ginsberg, J. P. (2017). An Overview of Heart Rate Variability Metrics and Norms. *Frontiers in Public Health*, *5*, 258. https://doi.org/10.3389/fpubh.2017.00258

Shankar, A., Hamer, M., McMunn, A., & Steptoe, A. (2013). Social isolation and loneliness: Relationships with cognitive function during 4 years of follow-up in the English Lon-

gitudinal Study of Ageing. *Psychosomatic Medicine*, *75*(2), 161–170. https://doi.org/10.1097/PSY.0b013e31827f09cd

Shao, F., Han, X., Shao, S., & Wang, W. (2013). Adolescent social isolation influences cognitive function in adult rats. *Neural Regeneration Research*, *8*(11), 1025–1030. https://doi.org/10.3969/j.issn.1673-5374.2013.11.008

Shiffman, S., Stone, A. A., & Hufford, M. R. (2008). Ecological momentary assessment. *Annual Review of Clinical Psychology*, *4*, 1–32. https://doi.org/10.1146/annurev.clinpsy.3.022806.091415

Skinner, B. F. (1976). *Walden Two*. Macmillan.

Smith, P. S. (2006). The Effects of Solitary Confinement on Prison Inmates: A Brief History and Review of the Literature. *Crime and Justice*, *34*(1), 441–528. https://doi.org/10.1086/500626

Smith, K. P., & Christakis, N. A. (2008). Social Networks and Health. *Annual Review of Sociology*, *34*(1), 405–429. https://doi.org/10.1146/annurev.soc.34.040507.134601

Smith, T., & French, J. (1997). Psychosocial Stress and Urinary Cortisol Excretion in Marmoset Monkeys. *Physiology & Behavior*, *62*(2), 225–232. https://doi.org/10.1016/S0031-9384(97)00103-0

Stang, J., Moe, J., Teigset, I. A., Østberg, B., & Moger, T. A. (2003). Fanger i sikkerhetscelle—En utfordring. *Tidsskrift for Den Norske Lægeforening*, *123*(13–14), 1844–46.

Steptoe, A., Owen, N., Kunz-Ebrecht, S. R., & Brydon, L. (2004). Loneliness and neuroendocrine, cardiovascular, and inflammatory stress responses in middle-aged men and women. *Psychoneuroendocrinology*, *29*(5), 593–611. https://doi.org/10.1016/S0306-4530(03)00086-6

Stranahan, A. M., Khalil, D., & Gould, E. (2006). Social isolation delays the positive effects of running on adult neurogenesis. *Nature Neuroscience*, *9*(4), 526–533. https://doi.org/10.1038/nn1668

Stratakis, C. A., & Chrousos, G. P. (1995). Neuroendocrinology and pathophysiology of the stress system. *Annals of the New York Academy of Sciences*, *771*, 1–18. https://doi.org/10.1111/j.1749-6632.1995.tb44666.x

Talarico, J. M., & Rubin, D. C. (2003). Confidence, Not Consistency, Characterizes Flashbulb Memories. *Psychological Science*, *14*(5), 455–461. https://doi.org/10.1111/1467-9280.02453

Taylor, R. J., Taylor, H. O., & Chatters, L. M. (2016). Social Isolation from Extended Family Members and Friends among African Americans: Findings from a National Survey.

Journal of Family Social Work, *19*(5), 443–461. https://doi.org/10.1080/10522158.2016.1181127

Thompson, S. C. (1981). Will it hurt less if I can control it? A complex answer to a simple question. *Psychological Bulletin*, *90*(1), 89–101. https://doi.org/10.1037/0033-2909.90.1.89

Tomova, L., Wang, K. L., Thompson, T., Matthews, G. A., Takahashi, A., Tye, K. M., & Saxe, R. (2020). Acute social isolation evokes midbrain craving responses similar to hunger. *Nature Neuroscience*, *23*(12), 1597–1605. https://doi.org/10.1038/s41593-020-00742-z

Tranel, N. (1962). Effects of perceptual isolation on introverts and extraverts. *Journal of Psychiatric Research*, *1*, 185–192. https://doi.org/10.1016/0022-3956(62)90008-0

Uchino, B. N., Cacioppo, J. T., & Kiecolt-Glaser, J. K. (1996). The relationship between social support and physiological processes: A review with emphasis on underlying mechanisms and implications for health. *Psychological Bulletin*, *119*(3), 488–531. https://doi.org/10.1037/0033-2909.119.3.488

Uchino, B. N., & Garvey, T. S. (1997). The availability of social support reduces cardiovascular reactivity to acute psychological stress. *Journal of Behavioral Medicine*, *20*(1), 15–27. https://doi.org/10.1023/a:1025583012283

Ulrich-Lai, Y. M., & Herman, J. P. (2009). Neural regulation of endocrine and autonomic stress responses. *Nature Reviews. Neuroscience*, *10*(6), 397–409. https://doi.org/10.1038/nrn2647

Venniro, M., Zhang, M., Caprioli, D., Hoots, J. K., Golden, S. A., Heins, C., Morales, M., Epstein, D. H., & Shaham, Y. (2018). Volitional social interaction prevents drug addiction in rat models. *Nature Neuroscience*, *21*(11), 1520–1529. https://doi.org/10.1038/s41593-018-0246-6

Verbruggen, F., & Logan, G. D. (2008). Automatic and controlled response inhibition: Associative learning in the go/no-go and stop-signal paradigms. *Journal of Experimental Psychology. General*, *137*(4), 649–672. https://doi.org/10.1037/a0013170

Vittengl, J. R., & Holt, C. S. (1998). A time-series diary study of mood and social interaction. *Motivation and Emotion*, *22*(3), 255–275. https://doi.org/10.1023/A:1022388123550

vonDawans, B., Kirschbaum, C., & Heinrichs, M. (2011). The Trier Social Stress Test for Groups (TSST-G): A new research tool for controlled simultaneous social stress exposure in a group format. *Psychoneuroendocrinology*, *36*(4), 514–522. https://doi.org/10.1016/j.psyneuen.2010.08.004

Walker, W. R., Skowronski, J. J., Gibbons, J. A., Vogl, R. J., & Ritchie, T. D. (2009). Why people rehearse their memories: Frequency of use and relations to the intensity of emotions associated with autobiographical memories. *Memory*, *17*(7), 760–773. https://doi.org/10.1080/09658210903107846

Wang, Z., Faith, M., Patterson, F., Tang, K., Kerrin, K., Wileyto, E. P., Detre, J. A., & Lerman, C. (2007). Neural substrates of abstinence-induced cigarette cravings in chronic smokers. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, *27*(51), 14035–14040. https://doi.org/10.1523/JNEUROSCI.2966-07.2007

Watson, D., Clark, L. A., McIntyre, C. W., & Hamaker, S. (1992). Affect, personality, and social activity. *Journal of Personality and Social Psychology*, *63*(6), 1011–1025. https://doi.org/10.1037//0022-3514.63.6.1011

Williamson, G. M., & Clark, M. S. (1989). Providing help and desired relationship type as determinants of changes in moods and self-evaluations. *Journal of Personality and Social Psychology*, *56*(5), 722–734. https://doi.org/10.1037/0022-3514.56.5.722

Wilson, R. S., Krueger, K. R., Arnold, S. E., Schneider, J. A., Kelly, J. F., Barnes, L. L., Tang, Y., & Bennett, D. A. (2007). Loneliness and risk of Alzheimer disease. *Archives of General Psychiatry*, *64*(2), 234–240. https://doi.org/10.1001/archpsyc.64.2.234

Wittig, R. M., Crockford, C., Weltring, A., Langergraber, K. E., Deschner, T., & Zuberbühler, K. (2016). Social support reduces stress hormone levels in wild chimpanzees across stressful events and everyday affiliations. *Nature Communications*, *7*, 13361. https://doi.org/10.1038/ncomms13361

Wolffgramm, J., & Heyne, A. (1991). Social behavior, dominance, and social deprivation of rats determine drug choice. *Pharmacology, Biochemistry, and Behavior*, *38*(2), 389–399. https://doi.org/10.1016/0091-3057(91)90297-f

Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology*, *18*(5), 459–482. https://doi.org/10.1002/cne.920180503

Yiend, J. (2010). The effects of emotion on attention: A review of attentional processing of emotional information. *Cognition & Emotion*, *24*(1), 3–47. https://doi.org/10.1080/02699930903205698

Zhong, C.-B., & Leonardelli, G. J. (2008). Cold and lonely: Does social exclusion literally feel cold? *Psychological Science*, *19*(9), 838–842. https://doi.org/10.1111/j.1467-9280.2008.02165.x

Zunzunegui, M.-V., Alvarado, B. E., Del Ser, T., & Otero, A. (2003). Social networks, social integration, and social engagement determine cognitive decline in community-dwelling Spanish older adults. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences*, *58*(2), S93–S100. https://doi.org/10.1093/geronb/58.2.s93

13. Appendix

13.1. Abstract (English):

Chronic social isolation is connected to various health risks. Strong evidence is shown for an impact of long-term isolation on the mood and stress response. The questions addressed within this study aim to clarify whether also short-term isolation results in crucial differences of emotions and the cortisol stress response. To investigate this connection participants experienced different experimental sessions including an isolation period without and an analogous neutral session with social interaction over 8 h. Self-indicated emotional states (n = 24) and cortisol levels in the saliva (n = 16) were measured throughout the sessions and the mornings after, as indicators for mood states and stress. The random intercepts and slopes model assessing the interaction of time and condition revealed significant higher desires for social contact throughout the isolation session compared to the neutral session. In contrast no significant influence of short-term isolation was found on emotional states or on the endocrine stress response. The results imply an immediate increase of the desire to socially engage when isolated whereas emotional states and the physical stress response are unaffected within this short period. This suggests a sudden motivational drive to reengage with others without prompt psychological and physical discomforts.

Key words: social isolation, short-term social isolation, cortisol, stress, emotion, mood, experiment, objective social isolation

13.2. Abstract (Deutsch)

Chronische soziale Isolation ist mit verschiedenen Gesundheitsrisiken verbunden. Es gibt starke Hinweise auf einen Einfluss der langfristigen Isolation auf die Stimmung und die Stressreaktion. Die in dieser Studie behandelten Fragen zielen darauf ab zu klären, ob kurzfristige Isolation ebenfalls zu entscheidenden Auswirkungen auf Emotionen und die Cortisol-Stressreaktion führt. Um diesen Zusammenhang zu untersuchen, nahmen die Teilnehmer an verschiedenen experimentellen Sitzungen teil, einschließlich einer Isolationsperiode ohne und einer analogen neutralen Sitzung mit sozialer Interaktion, jeweils über einen Zeitraum von 8 Stunden. Selbst angegebene emotionale Zustände (n = 24) und der Cortisol-Spiegel im Speichel (n = 16) wurden während der Sitzungen und am darauffolgenden Morgen als Indikatoren für Stimmungszustände und Stress gemessen. Das für die statistische Analyse verwendete Random Intercepts and Slopes Modell, welches den Zusammenhang von Zeit und Bedingung erfasst, ergab im Vergleich zur neutralen Sitzung ein signifikant höheres Verlangen nach sozialem Kontakt während der Isolationsbedingung. Im Gegensatz dazu wurde kein signifikanter Einfluss der kurzfristigen sozialen Isolation auf emotionale Zustände oder die endokrine Stressreaktion festgestellt. Die Ergebnisse implizieren eine sofortige Zunahme des Wunsches, soziale Kontakte aufzunehmen, wenn isoliert, während Emotionen und die physische Stressreaktion in dieser kurzen Zeit nicht beeinflusst werden.

Schlüsselwörter: soziale Isolation, kurzfristige soziale Isolation, Cortisol, Stress, Emotionen, Stimmung, Experiment, objektive soziale Isolation

13.3. List of Figures

13.4. List of Tables

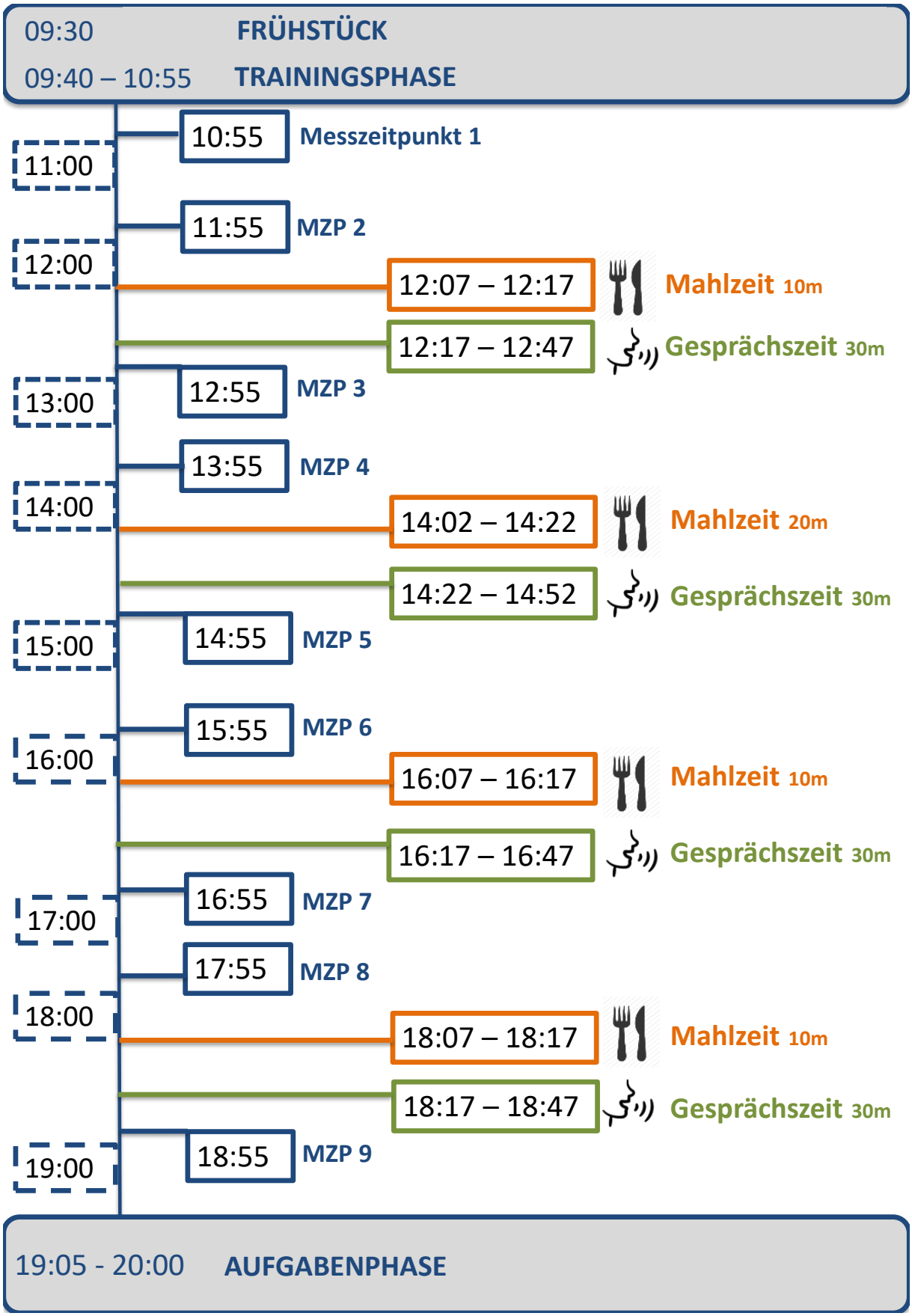
13.5. List of Abbreviations

ACTH	Adrenocorticotropic hormone
AI	Anterior insula
ANG	Anger dimesnion
ANS	Autonomic nervous system
bpm	Beat per minute
CA	Calmness – restlessness dimension
CAR	Cortisol-awakening-response

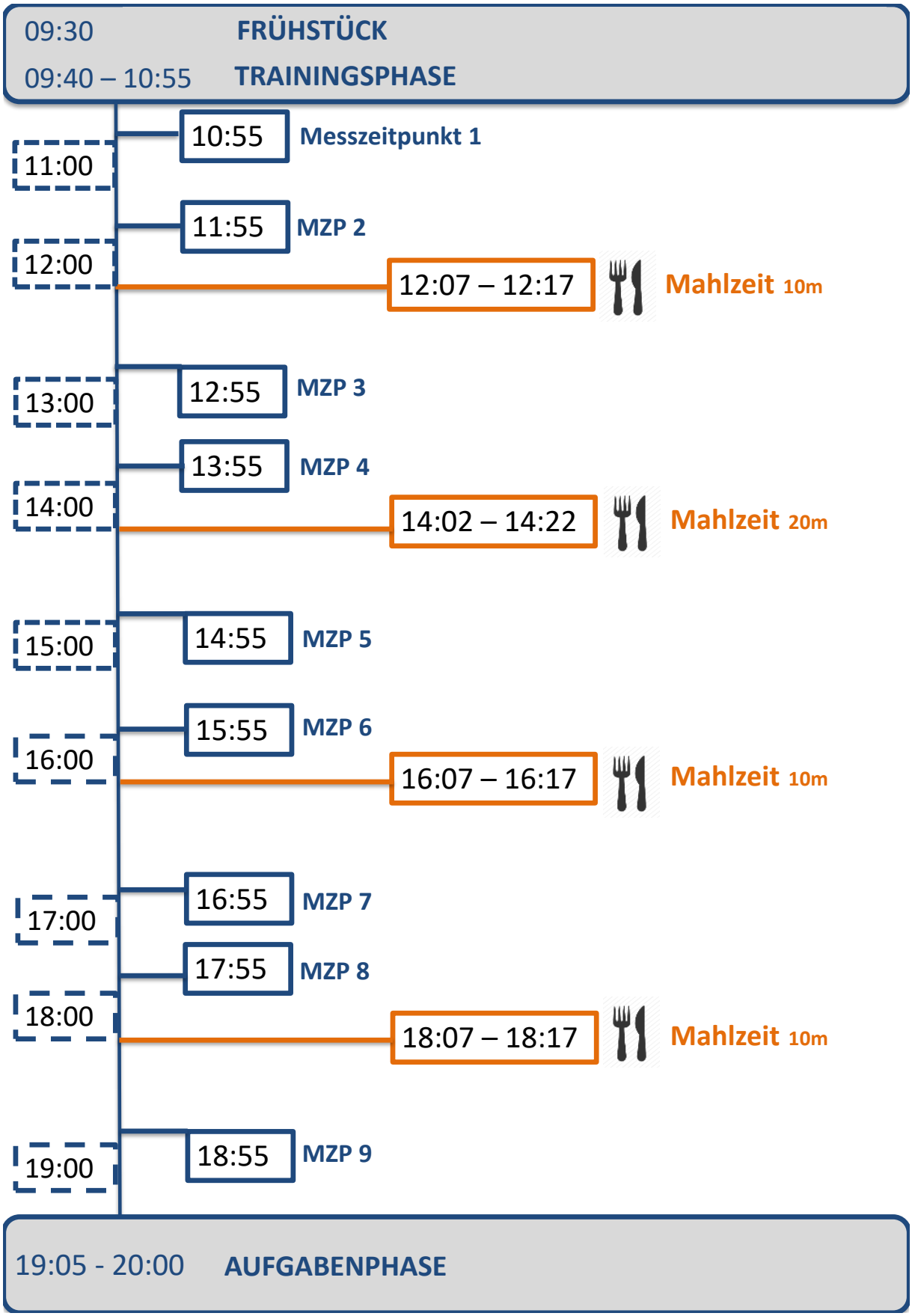
CRH	Cortical-releasing-hormone
EMA	Ecological momentary assessment
FAT	Fatigue
FIT	Finger Tapping Test
GB	Good – bad mood dimension
HNA-Axis	Hypothalamus-pituitary-adrenal axis
HOP	Hopelessness dimension
HPA-Axis	Hypothalamus-pituitary-adrenal axis
HR	Hear rate
IFG	Inferior frontal gyrus
MDBF	Multidimensional Mood Questionnaire German
POMS	Profile of Mood States
POS	Positive mood dimension
SAD	Sadness dimension
SCN	Suprachiasmatic nucleus
SD	Standard deviation
SN	Substantia nigra
VAS	Visual analogue scale
VTA	Ventral tegmental area
WT	Wakefulness – tiredness dimension

13.6. Supplementary Material

13.6.1. Timeline of the neutral session



13.6.2. Timeline oft the social isolation session



13.6.3. Manual for neutral session

(including all questions asked throughout the sessions with the iPod)

universität wien

Universität Wien

Der Einfluss von sozialen und nicht sozialen Bedürfnissen auf den körperlichen Zustand

Sitzungsmanual

Inhaltsverzeichnis

Vielen Dank für deine Teilnahme an dieser Studie!

Dieses Manual soll dich an alles erinnern, was du während der Trainingsphase eingeübt hast. Du kannst es jederzeit zu Rate ziehen, wenn du dir bei einer deiner Aufgaben unsicher bist.

Die Räumlichkeiten

10:55 - 19:05: Hauptraum

- Der Hauptraum besteht aus dem größten Raum in den Laborräumlichkeiten. Hier stehen dir verschiedene Gegenstände zur Beschäftigung, das Speichelproben-Kit und gemütliche Sitzmöglichkeiten zur Verfügung.
- Fühle dich frei deine eigenen, sowie auch alle anderen Gegenstände, die auf dem Tisch bereit stehen, zu benutzen! Du darfst frei entscheiden, wie du dich beschäftigst, es gibt keine Vorgaben.
- Bitte führe keine schweren körperlichen Übungen durch, die die Herzrate erhöhen.
- Bitte versuche nicht zu schlafen.
- Alle weiteren Räumlichkeiten um den Hauptraum herum sind Stauräume und andere Testräume, die dir vom Testleiter gezeigt wurden. Bitte betrete diese nicht.
- Du kannst während der gesamten Sitzung die Toilette am Ende des Gangs nutzen. Versuche im Hauptraum zu sein, wenn es Zeit für eine der geplanten Aktivitäten ist, die im nächsten Kapitel erklärt werden.
- Im Falle eines Notfalls gibt es einen Notausgang, der durch grüne Exit-Schilder gekennzeichnet ist.
- Lass die Tür zum Hauptraum immer geschlossen. Schließe die Tür immer, wenn du vom Gang zurück kommst.
- Die Tür zum Hauptraum wird manchmal für einen kurzen Zeitraum von maximal 2 Minuten abgeschlossen, wenn Mitarbeiter den Gang benutzen oder auf die Toilette gehen. Der Notausgang ist immer offen.
- Der Raum ist mit einer Kamera ausgestattet. Diese Kamera nimmt nichts auf. Das Bild wird auf den Computer der Testleiter übertragen und sie wird nur genutzt, damit die Testleiter sicherstellen können, dass alles gut verläuft. Es wird kein Ton übertragen und das Video nicht gespeichert.
- **Während dieser Phase ist es sehr wichtig, dass du den Testleiter nicht kontaktierst, außer: 1. es tritt ein Notfall ein (z.B. ein gesundheitliches Problem oder ein Alarm)**

ODER 2. du möchtest deine Teilnahme an der Studie beenden. Wenn du den Testleiter kontaktierst können wir deine Daten leider nicht mehr benutzen.

19:05 - 20:15: Aufgabenraum

- Du wirst durch den iPod darüber informiert, den Hauptraum zu verlassen und in den Aufgabenraum zu gehen.
- Hier wirst du alleine vier Aufgaben am Laptop durchführen: eine Aufgabe, in der du die Größe von Bildern veränderst und sie anschließend bewertest und drei kognitive Aufgaben. Die Aufgaben dauern zusammen mit den Übungsrunden ca. 60 Minuten.
- Am Ende der Aufgaben wird der Testleiter aus einem anderen Raum einen Fragebogen am Computer für dich öffnen, den du ausfüllen wirst. Der Testleiter kommt 5-10 Minuten später in den Raum. Achtung: es wird ein anderer Testleiter sein als am Vormittag.

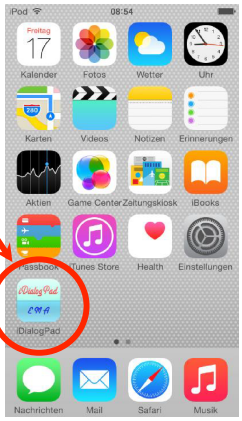
Ein Handbuch zur Nutzung des iPods

Der iPod informiert dich über alle Aktivitäten, die du im Laufe des Tages durchführst.

An der Wand hängt ein Zeitplan aller Aktivitäten. Der Beginn und das Ende jeder Aktivität wird durch den iPod per Alarm angekündigt. Bitte achte darauf, vor dem Beginn der Aktivitäten im Raum zu sein, um keinen Alarm zu verpassen.

Allgemeine Informationen zum iPod

- Bitte schalte den iPod nie ab.
- Achte darauf, dass der iPod immer aufgeladen ist.
- Die Tastensperre wird automatisch nach einer gewissen Zeit aktiviert. Falls der iPod auf Ruhezustand schaltet und der Bildschirm schwarz wird, kannst du auf den runden Hauptknopf, unten in der Mitte drücken. Anschließend erscheint wieder die Anzeige zum Entriegeln. Du kannst den iPod entriegeln, indem du von unten links nach unten rechts wischst.
- Bitte verstelle die Lautstärke nicht. Es ist wichtig, dass du jeden Alarm gut hörst.
- Du hast keinen Internetzugang am iPod. Bitte benutze das Gerät nur zum Ausfüllen von Fragebögen und Lesen von Benachrichtigungen.
- Die App, die wir zur Datenerhebung nutzen, heißt iDialogPad. Bleibe immer in der App. Falls du ungewollt aus der App herauskommst, öffne sie wieder.
- Verstelle die Lautstärke nicht. Es ist wichtig, dass du jeden Alarm gut hören kannst!
- Du hast keinen Internetzugang am iPod. Bitte verwende den iPod nur für die dafür vorgesehenen Zwecke.



- Dein Startscreen wird so aussehen. In der unteren Hälfte des Bildschirms ist die Zeit des nächsten Alarms zu sehen.
- Du musst die Fragebögen nie selbst öffnen. Sobald der iPod klingelt, wird die erste Frage automatisch aufgezeigt, wenn du den Bildschirm entsperrst.
- Der Alarm hört auf zu klingeln, wenn du die erste Antwort angibst.

Der iPod kann aus 3 möglichen Gründen klingeln:

1. **Messzeitpunkt**
2. **Mahlzeit**
3. **Gesprächszeit**

+ um dich darüber zu informieren in den Aufgabenraum zu gehen (19:05)

Messzeitpunkte

Der Alarm signalisiert einen Messzeitpunkt **5 Minuten vor jeder vollen Stunde** (10:55, 11:55, 12:55, 13:55, 14:55, 15:55, usw.)

Du wirst die Messung nur durchführen können, wenn du den Alarm hörst. Du kannst die Messung nicht selbst an einem anderen Zeitpunkt starten. Aus diesem Grund ist es wichtig, dass du an den vorgegeben Zeiten (5 vor jeder vollen Stunde) im Raum bist.

Bitte verpasse keinen Alarm!

Jeder Messzeitpunkt besteht aus zwei Teilen:

Teil 1: Fragebogen

Teil 2: Speichelprobe

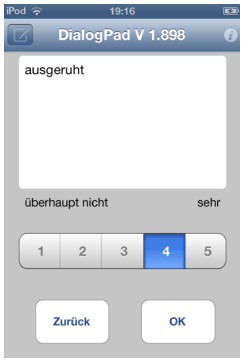
Die Fragebögen

Immer wenn du den Alarm hörst, erscheinen die Fragen automatisch, sobald du den iPod entsperrst. Beantworte sie alle. Die Fragebögen variieren in ihrer Länge, aber es dauert nie länger als 5 Minuten, um sie auszufüllen. *Bitte nimm dir Zeit, die Fragen aufmerksam zu lesen!*

Die Fragen erscheinen nacheinander auf dem Bildschirm. Wenn du deine Antwort noch einmal verändern willst, drücke auf den Zurück-Button. ACHTUNG: du kannst immer nur eine Frage zurück springen.

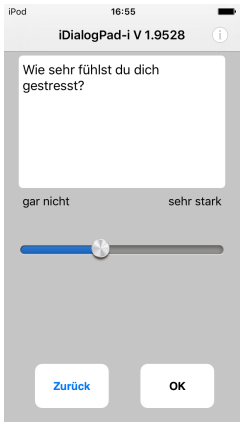
Nummerskalen (von 1-5, oder 1-7)

- Drücke die Nummer, die du auswählen möchtest.
- Achtung, die Bedeutung der Nummern kann je nach Frage variieren! Schau dir die Labels (z.B.: überhaupt nicht/ sehr) über der Skala an, da diese die Bedeutung der höchsten und niedrigsten Nummer kennzeichnen.
- Bestätige die Auswahl mit OK (dieser Button taucht auf, sobald du eine Nummer angeklickt hast).



Analoge Skalen

- Hier kannst du die Frage beantworten, indem du den grauen Knopf in die Richtung des Labels verschiebst, das auf dich zutrifft (hier "überhaupt nicht intensiv" oder "intensiv").
- In diesem Beispiel wurde der Knopf (noch) nicht von der Mitte wegbewegt.



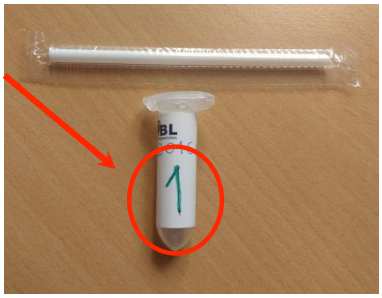
Fragen zu deinem momentanen Zustand

Du wirst nicht bei jedem Messzeitpunkt die gleichen Fragen beantworten. Manche Fragen wiederholen sich öfter als andere. Schau dir diese Liste an, falls dir einige Fragen unklar sind oder du die Anfangsfrage vergessen hast, nachdem du begonnen hast, die individuellen Items zu beantworten.

Frage	**Erklärung und einzelne Auswahlmöglichkeiten**
„Im Moment fühle ich mich…“	Hierzu wird dir eine Liste mit Auswahlmöglichkeiten präsentiert, für jede Möglichkeit stufe bitte auf einer Skala von 1 (überhaupt nicht) bis 5 (sehr) ein, inwieweit diese momentan auf dich zutrifft: ● zufrieden ● ausgeruht ● ruhelos ● schlecht ● schlapp ● gelassen ● müde ● gut ● unruhig ● munter ● unwohl ● entspannt ● gestresst ● erschöpft ● unmotiviert ● aktiv ● Im Moment kann ich mich gut konzentrieren ● Im Moment traue ich mir körperlich viel zu ● schläfrig ● wohl ● ausgeglichen ● unglücklich ● wach ● unzufrieden ● angespannt ● frisch ● glücklich ● nervös ● ermattet ● ruhig
*„Nachfolgend finden Sie eine Liste mit Wörtern, die verschiedene Gefühle und Gefühlszustände beschreiben. Bitte lesen Sie sorgfältig jedes einzelne Wort und kreuzen Sie dann die Zahl an, die am besten Ihren Gefühlszustand **im Moment** beschreibt. Bitte machen Sie bei jeder Aussage ein Kreuz.”*	Hierzu wird dir eine Liste mit Auswahlmöglichkeiten präsentiert, für jede Möglichkeit stufe bitte auf einer Skala von 1 (überhaupt nicht) bis 7 (sehr stark) ein, inwieweit diese momentan auf dich zutrifft: ● zornig ● abgeschlafft ● unglücklich ● traurig ● angenehm ● betrübt ● freudig

	● hoffnungslos ● müde ● verärgert ● frohgemut ● entmutigt ● fröhlich ● erschöpft ● heiter ● verzweifelt ● wütend ● entkräftet ● lustig
"Wie groß schätzen Sie Ihre Angst im Moment ein?"	Beantworte die Frage auf der analogen Skala von “keine Angst” (ganz links) zu “grosse Angst” (ganz rechts).
"Wie sehr haben Sie die Situation unter Kontrolle?" *"Wie sehr fühlen Sie sich gestresst?"* *"Wie stark ist Ihr Bedürfnis diese Situation zu verlassen?"* *"Wie hungrig fühlen Sie sich im Moment?"* *"Wie einsam fühlen Sie sich im Moment?"* *"Wie gelangweilt fühlen Sie sich im Moment?"*	Beantworte diese Fragen auf der analogen Skala von “gar nicht” (ganz links) zu “sehr stark” (ganz rechts).
"Wie stark ist dein Wunsch nach Essen im Moment?" *"Wie stark ist dein Wunsch nach sozialem Kontakt im Moment?" ** *"Wie stark ist dein Wunsch, dein Handy im Moment zu benutzen?"* *"Wie stark ist dein Wunsch, das Internet im Moment zu benutzen?"*	Beantworte diese Fragen auf der analogen Skala von “überhaupt nicht” (ganz links) zu “sehr stark” (ganz rechts). ***'Sozialer Kontakt' stellt einen oder mehrere der folgenden Punkte dar: Jemanden sehen, hören, berühren und mit jemandem sprechen.**

Die Speichelproben



Direkt nachdem du alle Fragen beantwortet hast, wirst du darum gebeten, eine Speichelprobe abzugeben. Du wirst anhand von Anweisungen am Bildschirm durch die Prozedur geleitet. Bitte benutze die Speichelgefäße (Salicaps) nur, wenn du die Anweisung dazu bekommst. Du hast genau 9 Behälter. In der Tabelle darunter kannst du genau sehen, welche Gefäßnummer zu welchem Zeitpunkt benutzt werden soll. Du wirst auch durch den iPod die Information bekommen, welche Nummer du nehmen sollst.

Messzeitpunkt Nummer (Zeit)	Salicap Nummer
1 (10:55)	1
2 (11:55)	2
3 (12:55)	3
4 (13:55)	4
5 (14:55)	5
6 (15:55)	6
7 (16:55)	7
8 (17:55)	8
9 (18:55)	9

Bitte lies alle Anweisungen am iPod aufmerksam durch!

1. Nimm das Speichelgefäß (Salicap) mit der richtigen Nummer (in der App und in der Tabelle oben angegeben). Bereite einen Strohhalm vor.

2. Vor jeder Probennahme solltest Du, wenn möglich, deinen Mund mit Wasser ausspülen. Anschließend bitten wir dich, einmal komplett allen im Mund befindlichen Speichel herunterzuschlucken bzw. auszuspucken.

3. Sammele nun für 2 Minuten den Speichel im Mund, ohne den Speichel hinunterzuschlucken und ohne absichtlich den Speichelfluss anzuregen. Hierfür ist im iPod eine Zeituhr eingestellt.

4. Spucke anschließend über den Strohhalm den komplett gesammelten Speichel in das Salicap. Lege den Strohhalm vor dir auf ein Taschentuch.

5. Gebe die Nummer des Salicap-Gefäßes in der App ein. Gebe dann die richtige Uhrzeit an.

6. Achte darauf, das Salicap gut zu verschließen und verstaue es in der Kühlbox, in dem Plastikbeutel. Schließe den Plastikbeutel fest zu und achte darauf, dass er gut von den Kühlakkus bedeckt ist.

Wirf den Strohhalm in den Mülleimer.

Mahlzeiten

Du bekommst jede zweite Stunde eine Mahlzeit: um 12:07, 14:02, 16:07 und 18:07. Sie werden immer nach den Messzeitpunkten vergeben. Du wirst durch die Benachrichtigungen am iPod über Beginn und Ende der Mahlzeiten informiert.

Für den Zweck dieser Studie ist es sehr wichtig, dass du zu den genau vorgegebenen Zeiten isst! Die Kalorienanzahl und Zeiten der Mahlzeit sind bei allen Teilnehmerinnen gleich, daher ist es nicht möglich, dass du mehr Essen bekommst oder zu einer anderen Zeit isst. Du bekommst im Laufe des Tages drei Snacks und ein Mittagessen.

Mahlzeiten	**Zeiträume**
Snack 1	12:07 – 12:17 (10 Minuten)
Mittagessen	14:02 – 14:22 (20 Minuten)
Snack 2	16:07 – 16:17 (10 Minuten)
Snack 3	18:07 – 18:17 (10 Minuten)

Du bekommst für jede Mahlzeit folgende Benachrichtigungen:

- **Wenn es Zeit ist, die Mahlzeit zu beginnen**. Du wirst aufgefordert, das Essen vom Gang zu holen. Der Teller steht auf einem Tisch vor der Haupttür. Du hast 10 Minuten Zeit für einen Snack und 20 Minuten Zeit für das Mittagessen.
- **3 Minuten, bevor du deine Mahlzeit beenden sollst.** In den darauffolgenden Minuten solltest du die Mahlzeit beenden
- **Wenn es Zeit ist, die Mahlzeit zu beenden**. Sobald du die Benachrichtigung bekommst, bitte bringe die Teller (und ggf. die Essensreste) zurück vor die Tür in die dafür vorgesehene Box unter dem Tisch. Zur gleichen Zeit wirst du dazu aufgefordert, den Laptop und das Handy für die Gesprächszeit vom Tisch zu holen (siehe nächstes Kapitel).

Wichtig! Bitte lasse jegliche Essensreste (auch Bananenschalen o.ä.) nach der Mahlzeit auf dem Teller liegen.

Gesprächszeiten

Nach jeder Mahlzeit wirst du Gesprächszeit haben, die du dir im Voraus mit jemandem ausgemacht hast. Jede Gesprächszeit dauert 30 Minuten.

Für den Zweck dieser Studie ist es sehr wichtig, dass du mit deinen Gesprächspartnern zu der genau ausgemachten Zeit kommunizierst! Es ist nicht möglich die Zeiträume zu verändern. Es ist möglich mit mehreren Personen während eines Zeitraums oder mit der gleichen Person zu verschiedenen Zeiträumen zu sprechen. Du kannst auch deine "Notfallkontakte" anrufen, falls ein Gespräch frühzeitig beendet wird.

Deine Gespräche verlaufen komplett privat ab - niemand wird sie abhören, beobachten oder irgendwie analysieren. Fühl dich frei mit deinen Gesprächspartnern zu sprechen so wie immer.

Laptop und Handy sind nur für die Gesprächszeiten vorgesehen und du hast auch keinen Internetzugang. Daher ist es wichtig, dass du diese nur für die geplanten Gespräche benutzt!

Gesprächszeit	**Zeit**
1.	12:17 – 12:47
2.	14:25 – 14:55
3.	16:17 – 16:47
4.	18:17 – 18:47

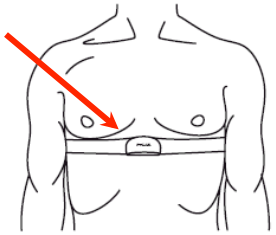
Du bekommst für jede Gesprächszeit folgende Benachrichtigungen:

- **Wenn es Zeit ist, das Gespräch zu beginnen.** Diese Benachrichtigung erhältst du zur gleichen Zeit, wie die Benachrichtigung die Mahlzeit zu beenden. Hole den Laptop und das Handy beide vom Tisch vor der Haupttür.
  - Klappe den Laptop dabei nicht zusammen!
  - Falls du den Laptop benutzt: Bringe den Laptop in den Hauptraum zum Tisch neben dem Fenster und verbinde ihn mit dem Internetkabel.
  - Warte bis die Internetverbindung hergestellt ist. Du kannst dies an dem Zeichen in der unteren rechten Ecke erkennen.
  - Skype ist bereits geöffnet. Logge dich mit Username und Password ein. Starte die Gesprächszeit, sobald du bereit bist.
  - Um die Lautstärke zu verändern, klicke FN + Pfeil-Oben, bzw. FN + Pfeil-Unten
  - Um die Helligkeit zu verändern, kliche FN + Pfeil-Rechts, bzw. FN ü Pfeil-Links
- 3 Minuten, bevor die Gesprächszeit zu Ende ist. Bereite dich darauf vor, das Gespräch bald zu beenden.
- **Wenn es Zeit ist, das Gespräch zu beenden.** Sobald du diese Benachrichtigung erhältst, logge dich bitte aus Skype aus und stecke das Internetkabel aus. Bringe Laptop und Handy wieder zurück auf den Tisch vor die Tür.

Messung der Herzrate

Während der gesamten Sitzung wird deine Herzrate mithilfe des Polar-Gürtels gemessen.

Achte darauf, den Gürtel direkt unter deiner Brust zu befestigen. Der Sensor sollte sich in der Mitte befinden. Der Gürtel sollte fest sitzen, aber gleichzeitig nicht ungemütlich sein.



Es ist sehr wichtig, dass der Gürtel sich während der gesamten Sitzung nicht bewegt! Bitte entferne den Gürtel während der gesamten Sitzung nicht, bis du am Ende des Tages (ca. 20:00) dazu aufgefordert wirst.

Falls der Gürtel herunter rutscht, versuche ihn so schnell wie möglich wieder in die richtige Position zu bringen und etwas fester zu ziehen. Die Aufnahme der Herzrate erfolgt weiterhin von selbst.

Die Computeraufgaben

Kurz nachdem du deinen letzten Messzeitpunkt abgeschlossen hast, erhältst du die Benachrichtigung zum Aufgabenraum zu gehen (Zeit: **19:05**). Du kannst dir ein Glas Wasser mitnehmen.

Setze dich im Aufgabenraum vor den Laptop. Du siehst zunächst die Benachrichtigung *"Drücken Sie die Leertaste, sobald Sie bereit sind mit den Anweisungen zu beginnen".* Beginne, sobald du bereit bist, indem du auf die Enter-Taste drückst. Du wirst darum gebeten, deinen Stuhl in die richtige Position zu rücken und deinen Körper und deine Hand wie auf den Bildern zu positionieren. Dies ist wichtig, um verzerrte Ergebnisse zu vermeiden. Du wirst ca. 50 Minuten für die Computeraufgaben brauchen. Du wirst 4 Aufgaben durchführen: eine Aufgabe, in der du Bilder vergrößerst und bewertest und drei kognitive Aufgaben. Zwischen der ersten und den anderen drei Aufgaben wirst du eine kurze Pause haben (3 Minuten).

Bitte halte dich genau an die Anweisungen am Bildschirm! Du wirst einige Probedurchläufe vor jeder Aufgabe durchführen. Obwohl du alle Aufgaben vorhin bereits geübt hast, ist es wichtig, dass du die Anweisungen aufmerksam durchliest. Du kannst diese nur einmal lesen, bevor du die Probedurchläufe beginnst.

Nachdem du die Aufgaben abgeschlossen hast, wird der Testleiter aus einem anderen Raum einen Fragebogen für dich am Computer öffnen. Der Testleiter kommt 5-10 Minuten später zu dir in den Aufgabenraum, um dich zu begrüßen und dir die nächsten Schritte zu erklären. Wundere dich nicht: es wird ein anderer Testleiter sein, als am Vormittag!

Viel Spaß und eine angenehme Zeit im Hauptraum!

13.6.4. Sheet to schedule the conversations slots

Gesprächszeiten

Während Ihrer Sitzung werden Sie 4 Gesprächszeiten haben, die jeweils 30 Minuten dauern. Sie werden Handy und Laptop der Universität für die Gespräche verwenden.

Sie werden Zugang zu den Kontakten haben, die Sie in die untenstehende Tabelle eintragen. Alle Nummern die Sie unten eintragen, werden für kurze Zeit an dem Handy der Universität gespeichert und nach Ende Ihrer Sitzung sofort wieder gelöscht.

Falls Sie möchten, werden Sie ebenfalls Ihren eigenen Skype-Account verwenden können und zu all Ihren Skype-Kontakten Zugang haben. Bitte vergewissern Sie sich vor der Sitzung, dass Sie ihren Skype-Username und Ihr Passwort für Skype parat haben.

Notieren Sie die Namen Ihrer Gesprächspartner in der Tabelle so, dass Sie sie später wiedererkennen (Spitznamen), daneben die Telefonnummer und den Skype-Namen (falls erforderlich). Notieren Sie zusätzlich einige Ersatzkontakte, die Sie anrufen können falls ein Gespräch frühzeitig beendet wird oder das geplante Gespräch nicht zustande kommt.

Bitte erinnern Sie Ihre Gesprächspartner noch vor der Sitzung an den Termin. Informieren Sie Ihre Gesprächspartner, dass diese nicht mit Ihrem eigenen Handy angerufen werden. Das Handy der Universität hat eine anonyme Nummer. Daher wird bei einem eingehenden Anruf “Private number” auf dem Display Ihrer Gesprächspartner aufscheinen.

Die Struktur der Studie erlaubt keine Abweichungen der Gesprächstermine. Die von Ihnen gewählten Gesprächspartner müssen innerhalb der folgenden Gesprächszeiten verfügbar sein:

12:17-12:47

14:22-14:52

16:17-16:47

18:17-18:47

Sie können auch mit der gleichen Person zu verschiedenen Gesprächszeiten kommunizieren oder mit ein paar Personen innerhalb einer Gesprächszeit.

Bitte senden Sie uns den Gesprächszeitenplan spätestens 3 Tage vor der Sitzung zu. Falls es zu Veränderungen bezüglich der Termine kommen sollte, informieren Sie uns bitte so schnell wie möglich!

Dieser Plan dient Ihnen auch als Erinnerung während der Sitzung.

Gesprächszeiten

Haupttermine

Datum: 06.11.20

Zeit	Name des/der Gesprächspartner/in	Telefonnummer	Skype-Name
12:15 – 12:47	Paul	—068181929007	/
14:20 – 14:52	Miriam	—066473480587	/
16:15 – 16:47	Benjamin	—066473034370	/
18:15 – 18:47	Paul	—068181929007	/

Ersatzkontakte (mindestens 3)

Name des/der Gesprächspartner/in	Telefonnummer	Skype-Name
Mama	—066473138549	/
Franzi	—068110724143	/
Paul	—068181929007	/

13.6.5. Food manual including meal options served throughout sessions

Frühstück ~ 360 kCal

3 Stück Toast (Ölz Mehrkorn Toast)
10g Marmelade pro Toast (Darbo Erdbeermarmelade/Marillenmarmelade)
3g Butter (vegan) pro Toast (Becel, 618kcal/100g)
140ml Orangensaft (Happy Day 100% Orange Vitamin C)

Mittagessen 1 ~ 600 kCal

128g Spaghetti (Barilla n.5 Spaghetti)
200g Tomatosauce (Barilla Napoletaner)
for vegans

(Mittagessen 2) ~ 600 kCal

128g Spaghetti (Barilla n.5 Spaghetti)
32g Pesto (Barilla I Pesti con Basilico e Rucola)

Snack 1 ~ 120 kCal
1 Banane (130-140g)

Snack 2 ~ 120 kCal
4 Stück Kekse (Leibniz Vollkorn Kekse)
for vegans: around 27g of Veganz Keks

Snack 3 ~ 120 kCal
7 Stück Cracker (TUC Original)
for vegans: around 27g Solleti Cracker

Abend Snack (n/a, but 500 kCal offered on the plate)
9 Stück Cookies (Alnatura Dinkel Doppelkeks)
for vegans: 10 DM Bio Dinkel Doppelkekse

13.6.6. Results overview

- **Questionnaire data** – Random intercepts and slopes model
- **Cortisol data** – Session data = Random intercepts and slopes model & CAR data = paired t-Test
- **HR data** – Random intercepts and slopes model
- **FIT data** – paired t -Test
- **GO-NO-GO data** – paired t-Test
- **2-Back task** – paired t-Test
- **3-Back task** – paired t-Test

Questionaire data:		Cohen's d	P Value	F value	df	estimate
MDBF						
good_bad	Group	-0.082	0.8456	0.0388	22.897	-0.099
	Hour		0.3149	1.0549	23.391	-0.014
	Group:hour	-0.110	0.7929	0.0705	23.138	-0.009
Wakeful-ness_Tiredness	Group	-0.316	0.09094.	2.9057	116.045	-0.731
	Hour		0.05494.	4.0964	22.628	-0.051
	Group:hour	0.124	0.49029	0.4787	124.971	0.021
Calm_Agitated	Group	0.036	0.93403	0.0070	22.100	0.032
	Hour		0.04924*	4.2764	24.766	-0.028
	Group:hour	-0.126	0.76819	0.0890	22.513	-0.008

Note. Group = main effect of condition, Hour = main effect of time, Group:hour = interaction effect of condition and time. *<.05, **<.01, ***<.001

POMS		Cohen's d	P Value	F value	df	estimate
sadness	Group	0.138	0.7284	0.1232	26.014	0.160
	Hour		0.5599	0.3496	23.844	0.007
	Group:hour	0.086	0.8250	0.0498	27.146	0.007
hopelesness	Group	0.203	0.5943	0.2902	28.087	0.257
	Hour		0.4509	0.5876	23.905	0.019
	Group:hour	-0.143	0.6890	0.1631	32.014	-0.012
fatigue	Group	0.166	0.572733	0.3227	46.815	0.434
	Hour		0.006076**	9.1485	22.759	0.084
	Group:hour	0.068	0.792589	0.0698	59.826	0.013
positive_mood	Group	0.234	0.4694	0.5337	38.965	0.406
	Hour		0.1486	2.2334	23.069	-0.017
	Group:hour	-0.426	0.1653	1.9907	43.865	-0.053

anger	Group	-0.348	0.3982	0.7393	24.435	-1.853
	Hour		0.3650	0.8529	23.791	0.003
	Group:hour	0.365	0.3838	0.7873	23.655	0.161

Note. Group = main effect of condition, Hour = main effect of time, Group:hour = interaction effect of condition and time. *<.05, **<.01, ***<.001

MDBF- NO Outliers excluding <3SD		**Cohen's d**	**P Value**	**F value**	**df**	**estimate**
good_bad	Group	-0.072	0.867	0.0287	22.280	-0.081
	Hour		0.425	0.6599	22.968	-0.009
	Group:hour	-0.126	0.769	0.0883	22.317	-0.009
Wakefulness_Tiredness	Group	-0.316	0.09094 .	2.9057	116.045	-0.731
	Hour		0.05494 .	4.0964	22.628	-0.051
	Group:hour	0.124	0.49029	0.4787	124.971	0.021
Calm_Agitated	Group	0.127	0.77363	0.0849	21.204	0.103
	Hour		0.05813 .	3.9832	22.633	-0.016
	Group:hour	-0.204	0.64506	0.2184	20.977	-0.012

Note. Group = main effect of condition, Hour = main effect of time, Group:hour = interaction effect of condition and time. *<.05, **<.01, ***<.001

POMS - NO Outliers excluding <3SD		**Cohen's d**	**P Value**	**F value**	**df**	**estimate**
sadness	Group	-0.116	0.7758	0.0829	24.826	-0.117
	Hour		0.8841	0.0217	27.563	-0.008
	Group:hour	0.321	0.4181	0.6768	26.343	0.021
hopelesness	Group	0.134	0.7333	0.1186	26.480	0.143
	Hour		0.6193	0.2537	22.805	0.008
	Group:hour	-0.014	0.9691	0.0015	33.164	-0.001

fatigue	Group	0.247	0.44498	0.5954	38.965	0.602
	Hour		0.01626 *	6.7819	21.809	0.085
	Group:hour	-0.008	0.97874	0.0007	46.539	-0.001
positive_mood	Group	0.234	0.4694	0.5337	38.965	0.406
	Hour		0.1486	2.2334	23.069	-0.017
	Group:hour	-0.426	0.1653	1.9907	43.865	-0.053
anger	Group	0.125	0.7512	0.1026	26.434	0.147
	Hour		0.9951	0.0000	28.284	0.007
	Group:hour	-0.167	0.6719	0.1834	26.445	-0.014

Note. Group = main effect of condition, Hour = main effect of time, Group:hour = interaction effect of condition and time. *<.05, **<.01, ***<.001

VAS 9 time points		**Cohen's d**	**P Value**	**F value**	**df**	**estimate**
S1@Wie groß schätzt du deine Angst im Moment ein?	Group	0.078	0.8528	0.0352	22.912	2.356
"*How anxious do you feel at the moment?"*	Hour		0.9897	0.0002	24.498	0.067
	Group:hour	-0.071	0.8662	0.0290	22.887	-0.140
S2@Wie sehr hast du die Situation unter Kontrolle?	Group	-0.063	0.8820	0.0225	22.988	-2.424
"How much do you have the situation under control?	Hour		0.6162	0.2582	23.106	-0.267
	Group:hour	0.010	0.9818	0.0005	22.666	0.021
S3@Wie sehr fühlst du dich sich gestresst?	Group	-0.062	0.8826	0.0223	22.871	-1.922
"How stressed do you feel?"	Hour		0.4952	0.4802	23.118	0.266
	Group:hour	0.048	0.9094	0.0132	22.765	0.093

S4@Wie stark ist dein Bedürfnis diese Situation zu verlassen?	Group	0.091	0.8293272	0.0475	22.861	3.955
"How strong is your need to leave this situation?".	Hour		0.0001744***	19.9658	23.050	3.455
	Group:hour	0.061	0.8859441	0.0210	22.627	0.171

Note. Group = main effect of condition, Hour = main effect of time, Group:hour = interaction effect of condition and time. *<.05, **<.01, ***<.001

VAS 5 time points		**Cohen's d**	**P Value**	**F value**	**df**	**estimate**
Df@Wie stark ist dein Wunsch nach Essen im Moment?	Group	0.107	0.7845	0.0763	26.77	5.080
„*How strong is your desire for food at the moment?"*	Hour		0.3321	0.9798	24.07	0.853
	Group:hour	-0.073	0.8363	0.0434	32.54	-0.230
Dc@Wie stark ist dein Wunsch nach sozialem Kontakt im Moment?	Group	-0.568	0.1869166	1.8508	22.934	-25.696
"*How strong is your desire for social contact right now?"*	Hour		0.0003645***	16.7474	26.130	0.864
	Group:hour	0.964	0.0297399*	5.3665	23.112	2.780
H@Wie hungrig fühlst du dich im Moment?	Group	-0.145	0.7008	0.1506	28.827	-5.995
"How hungry do you feel at the moment?"	Hour		0.9005	0.0160	24.276	-0.179
	Group:hour	0.184	0.5786	0.3140	37.074	0.527
L@Wie einsam fühlst du dich im Moment?	Group	-0.143	0.730881	0.1211	23.800	-5.424
"*How lonely do*	Hour		0.002505	11.3149	24.741	1.305

you feel at the moment?"						
	Group:hour	0.486	0.243259	1.4304	24.272	1.220
B@Wie gelang-weilt fühlst du dich im Moment?	Group	-0.142	0.6288652	0.2367	47.109	-6.883
"How bored do you feel at the moment?".	Hour		0.0001895***	19.5547	23.426	2.277
	Group:hour	0.436	0.2079487	1.6466	34.617	1.377

VAS 3 time points		**Cohen's d**	**P Value**	**F value**	**df**	**estimate**
Dp@Wie stark ist dein Wunsch, dein Handy im Moment zu benutzen?	Group	0.186	0.64907	0.2123	24.452	12.451
"*How strong is your desire to use your smartphone?"*	Hour		0.05524.	3.9892	29.042	1.767
	Group:hour	-0.041	0.91926	0.0105	25.215	-0.173
Di@Wie stark ist dein Wunsch, das Internet im Moment zu benutzen?	Group	-0.092	0.8241	0.0505	23.917	-6.353
"How strong is your desire to use the internet?"	Hour		0.1473	2.2331	25.666	0.792
	Group:hour	0.215	0.5939	0.2917	25.308	0.906

Note. Group = main effect of condition, Hour = main effect of time, Group:hour = interaction effect of condition and time. *<.05, **<.01, ***<.001

VAS 9 time points NO Outliers excluding <3SD		**Cohen's d**	**P Value**	**F value**	**df**	**estimate**
S1@Wie groß schätzt du deine Angst im Moment ein?	Group	-0.243	0.5786	0.3181	21.555	-3.918
	Hour		0.5326	0.4023	21.603	-0.267
	Group:hour	0.338	0.4410	0.6161	21.541	0.326

S2@Wie sehr hast du die Situation unter Kontrolle?	Group	-0.058	0.8917	0.0189	22.534	-2.215
	Hour		0.6270	0.2426	22.982	-0.268
	Group:hour	0.019	0.9649	0.0020	22.385	0.040
S3@Wie sehr fühlst du dich sich gestresst?	Group	-0.158	0.7154	0.1364	21.958	-3.688
	Hour		0.7171	0.1345	23.332	0.002
	Group:hour	0.206	0.6369	0.2293	21.672	0.282
S4@Wie stark ist dein Bedürfnis diese Situation zu verlassen?	Group	0.091	0.8293272	0.0475	22.861	3.955
	Hour		0.0001744***	19.9658	23.050	3.455
	Group:hour	0.061	0.8859441	0.0210	22.627	0.171
VAS 5 time points NO Outliers excluding <3SD		**Cohen's d**	**P Value**	**F value**	**df**	**estimate**
Df@Wie stark ist dein Wunsch nach Essen im Moment?	Group	0.107	0.7845	0.0763	26.77	5.080
	Hour		0.3321	0.9798	24.07	0.853
	Group:hour	-0.073	0.8363	0.0434	32.54	-0.230
Dc@Wie stark ist dein Wunsch nach sozialem Kontakt im Moment?	Group	-0.568	0.1869166	1.8508	22.934	-25.696
	Hour		0.0003645***	16.7474	26.130	0.864
	Group:hour	0.964	0.0297399*	5.3665	23.112	2.780
H@Wie hungrig fühlst du dich im Moment?	Group	-0.145	0.7008	0.1506	28.827	-5.995
	Hour		0.9005	0.0160	24.276	-0.179
	Group:hour	0.184	0.5786	0.3140	37.074	0.527

L@Wie einsam fühlst du dich im Moment?	Group	-0.143	0.730881	0.1211	23.800	-5.424
	Hour		0.002505**	11.3149	24.741	1.305
	Group:hour	0.486	0.243259	1.4304	24.272	1.220
B@Wie gelang-weilt fühlst du dich im Moment?	Group	-0.142	0.6288652	0.2367	47.109	-6.883
	Hour		0.0001895	19.5547	23.426	2.277
	Group:hour	0.436	0.2079487	1.6466	34.617	1.377
VAS 3 time points NO Outli-ers excluding <3SD		**Cohen's d**	**P Value**	**F value**	**df**	**estimate**
Dp@Wie stark ist dein Wunsch, dein Handy im Moment zu be-nutzen?	Group	0.186	0.64907	0.2123	24.452	12.451
	Hour		0.05524 .	3.9892	29.042	1.767
	Group:hour	-0.041	0.91926	0.0105	25.215	-0.173
Di@Wie stark ist dein Wunsch, das Internet im Mo-ment zu benut-zen?	Group	-0.092	0.8241	0.0505	23.917	-6.353
	Hour		0.1473	2.2331	25.666	0.792
	Group:hour	0.215	0.5939	0.2917	25.308	0.906

Note. Group = main effect of condition, Hour = main effect of time, Group:hour = interaction effect of condition and time. *<.05, **<.01, ***<.001

Cortisol data		**Cohen's d**	**P value**	**F value**	**df**	**estimate**
With log transformation	Group	0.124	0.7360	0.1158	29.980	0.057
	Hour		2.691e-12 *** 0.000	134.7194	28.398	-0.121
	Group:hour	-0.262	0.4909	0.4872	28.398	-0.015
Without log transformation	Group	0.141	0.6035	0.2729	55.215	0.129
	Hour		9.336e-05 ***	27.8221	15.004	-0.323
	Group:hour	-0.185	0.5812	0.3099	36.203	-0.026

Note. Group = main effect of condition, Hour = main effect of time, Group:hour = interaction effect of condition and time. *<.05, **<.01, ***<.001

t-test cort morning awakening	**Cohen's d**	**P value**	**t-value**	**df**	**Mean of difference**
	0.902808475	0.1119	1.689	15	1.402745

HR Data		**Cohen's d**	**P value**	**F value**	**df**	**estimate**
HR 8 hours	Group	0.181	0.65805	0.2007	24.624	0.500
	Hour		0.01235*	7.2511	25.503	0.187
	Group:hour	0.076	0.76778	0.0880	60.987	0.041
HR Data excluding first 4 hours -		**Cohen's d**	**P value**	**F value**	**df**	**estimate**
	Group	0.330	0.269445	1.2497	45.790	1.728
	Hour		0.006606 **	8.8232	24.286	-0.366
	Group:hour	-0.154	0.543059	0.3740	62.852	-0.146

Note. Group = main effect of condition, Hour = main effect of time, Group:hour = interaction effect of condition and time. *<.05, **<.001, ***<.0001

Absolute numbers	Mean	74.17189 HR In control	75.18295 HR In isolation

Cognitive tasks		**t-value**	**Cohen's d**	**P value**	**df**	**Mean of difference**
FIT right hand		0.83535	0.348365	0.4121	23	0.555555
	Absolute means right hand:	30.98611 taps in control	30.43056 taps in isolation			
		t-value	**Cohen's d**	**P value**	**df**	**Mean of difference**
FIT left hand		0.88147	0.367598	0.3872	23	0.6388888
	Absolute means left hand:	26.79167 taps in control	26.15278 taps in isolation			
		t-value	**Cohen's d**	**P value**	**df**	**Mean of difference**
GO-NO-GO		1.5503	0.64651979	0.1347	23	0.008333333
	Total numbers of mistakes:	451 mistakes (11549 right) in control	351 mistakes (11649 right) in isolation	Aprox. Each participant had 4 more mistakes in control		
		t-value	**Cohen's d**	**P value**	**df**	**Mean of difference**
2-Back		0.38234	0.1594468	0.7057	23	0.005
	Total numbers of 2-back mistakes	205 mistakes (2195 right) In control	193 mistakes (2207 right) In isolation			
		t-value	**Cohen's d**	**P value**	**df**	**Mean of difference**
3-Back		1.5434	0.643642	0.1364	23	0.0275
	Total numbers of 3-Back mistakes	400 mistakes (2000 right) In control	334 mistakes (2066 right) In isolation			