Psychobiological mechanisms underlying the stress-reducing effects of music listening in daily life

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Abbreviations

ACTH	adrenocorticotropic hormone
ANS	autonomic nervous system
BMI	body mass index
CRH	corticotropin-releasing hormone
FMS	Fibromyalgia Syndrome
HLM	hierachical linear modeling
HPA axis	hypothalamic-pituitary-adrenal axis

1. Introduction

Stress is a common phenomenon of daily life (McEwen, 1998). Current estimates show that stress accounts for 30% of costs related to disease and accidents in Western societies (Nater, Gaab, Rief, & Ehlert, 2006). This prominent role of stress for health in present-day societies led the World Health Organization to declare stress as the major health threat of the 21st century.

When an individual experiences stress, both body and mind are affected. When stress occurs, stress-sensitive systems in the body are activated, including the hypothalamic-pituitary-adrenal (HPA) axis and the autonomic nervous system (ANS). While acute stress has an adaptive function, chronic stress can be a major health threat as it facilitates and/or exacerbates the manifestation of disease and illness (Godbout & Glaser, 2006). Consequently, chronic stress is associated with long-term dysfunctions in these systems, leading to disease and having a deleterious impact on health. Stress in everyday life is particularly harmful, as daily life stressors are associated with the occurrence of health problems (DeLongis, Folkman, & Lazarus, 1988). With stress playing a crucial role for health, interventions that target stress – especially in daily life – are essential.

Music listening might be one such intervention in daily life, as people have always used music intuitively for health-beneficial effects. Indeed, music listening has been used as therapeutic agent for centuries (MacDonald, Kreutz, & Mitchell, 2012b; Mornhinweg, 1992; Raglio & Oasi, 2015). Although evidence from experimental studies suggests that music listening is associated with health-beneficial effects (Bernatzky, Strickner, Presch, Wendtner, & Kullich, 2012; Kreutz, Murcia, & Bongard, 2012; MacDonald, Kreutz, & Mitchell, 2012a; Mitchell & MacDonald, 2012; Särkämö et al., 2008, 2014; Thoma & Nater, 2011; Västfjäll, Juslin, & Hartig, 2012), we do not yet know how effective music is and which underlying mechanisms are responsible for its beneficial effects. In this regard, it has been suggested that it is music's capacity to influence stress-sensitive systems in the body on a hormonal and autonomic level that mediates the health-beneficial effects of music listening (Altenmüller & Schlaug, 2012; Koelsch, 2010, 2014; Thoma & Nater, 2011). Although music listening has indeed been associated with stress-reducing effects (Chanda & Levitin, 2013; Pelletier, 2004; Thoma & Nater, 2011), most of the evidence on music listening and its stress-reducing effect was gathered either in experimental settings or by means of retrospective surveys. Only a limited number of studies have begun to investigate the beneficial effects of music listening in daily life (Juslin, Liljeström, Västfjäll, Barradas, & Silva, 2008; Randall, Rickard, & Vella-Brodrick, 2014;

van Goethem & Sloboda, 2011). Nevertheless, studying the effects of music listening in an ecologically valid setting is both important and relevant, as the artificial surroundings in experimental settings might limit the results to the constraints of the laboratory. The advantage of ambulatory assessment studies is that associations among variables of interest can be assessed repeatedly over time while participants are going about their daily routine (Bolger, Davis, & Rafaeli, 2003). Therefore, it is possible to study dynamic relations among variables of interest with a minimum of recall bias and a maximum of ecological validity (Smyth & Stone, 2003). Particularly in view of the fact that music listening is a popular activity of daily life, ambulatory assessment enables associations between music listening and stress to be assessed directly in daily life – thus 'capturing life as it is lived' (Bolger et al., 2003, p.579).

However, so far, no study has directly investigated the stress-reducing effect of music listening in daily life, as the aforementioned studies rather assessed effects of music listening on well-being than specifically on stress. Thus, many questions remain unanswered concerning this stress-reducing effect (e.g., what is stress-reducing about music listening?). Furthermore, psychobiological mechanisms underlying the potential stress-reducing effect of music listening in daily life remain unclear. Understanding these psychobiological mechanisms is a key step towards fostering the role of music listening as an evidence-based adjuvant treatment option for stress. While some people believe that it is common sense that for music to exert stress-reducing effects, it must be low in arousal, others claim that the stress-reducing effect varies depending on liking for the music. However, without understanding psychobiological mechanisms underlying the stress-reducing effect of music listening, recommendations on the use of music in daily life cannot be validly made.

Thus, so far, research has only just scratched the surface of music listening in daily life as a powerful stress intervention. Consequently, it is necessary to unravel the stress-reducing effect of music listening by exploring the exact nature of this beneficial effect. To achieve this, first it is essential to study the effects of music listening on stress in daily life. Second, it is necessary to elucidate what is stress-reducing about music listening. Third, psychobiological mechanisms underlying this stress-reducing effect of music listening in daily life need to be explored. In this regard, it should be tested whether the health-beneficial effect of music listening is mediated by a reduction in psychobiological stress in daily life.

1.1. Stress and health

Although stress is a ubiquitous phenomenon in daily life that can lead to disease, mechanisms underlying the health-diminishing effect of stress have not fully unraveled (McEwen, 1998). There are stress-sensitive systems in the body that are involved in the physiological stress response, including the endocrine system and the autonomic nervous system (ANS) among others. The stress response can have immediate, intermediate and prolonged effects on the body. Dysregulations in the systems involved in the stress response are associated with disease (Stratakis & Chrousos, 1995). Thus, it is the capacity of stressors to have a sustained impact on the physiological stress response that leads to detrimental effects of stress on health.

In this regard, the appraisal of a stressor is especially critical to the stress response, as illustrated in the transactional model of stress and coping (Lazarus, 1966; Lazarus & Folkman, 1984). Crucial to this appraisal-based model are psychological appraisal processes, namely primary appraisal, secondary appraisal, and reappraisal. The model posits that when faced with a stressor, primary appraisal processes analyze whether a stressor is classified as positive, dangerous, or irrelevant. Only in case of an interpretation as dangerous do secondary appraisal processes analyze whether resources are sufficient or insufficient. In the case of insufficient resources, coping is necessary to overcome the stress. Within this theory, stress is defined as appraisal of a situation as dangerous in the presence of insufficient resources for coping with the stressor, which can be classified as harm, threat, or challenge. Empirical laboratory evidence suggests that appraisal processes are associated with the physiological stress response (Gaab, Rohleder, Nater, & Ehlert, 2005; Tomaka, Blascovich, Kelsey, & Leitten, 1993) and might therefore explain how effects of stress translate into diminished health.

Whereas the aforementioned model focuses on individual cognitive appraisal processes, the concept of homeostasis refers to biological processes related to stress that are thought to be invariant across individuals. The term homeostasis dates back to Cannon (1932), who coined the term fight-or-flight response as an organism's reaction to threat. Based on the assumption that homeostasis, that is, an equilibrium of bodily functions, is necessary for survival, any intrinsic or extrinsic factors challenging this homeostasis can be referred to as stressors (Chrousos & Gold, 1992). In this regard, Selye (1973) proposed the general adaptation syndrome model, according to which stressors activate the body ('a defense reaction'), which is mediated by the nervous and the hormone system. With prolonged stress, a succession of three stages is suggested, ranging from shock, to adaptation, and finally to exhaustion. The latter in particular explains negative effects of stress on health. Detrimental effects of stress on health are thus conceptualized as maladaptation processes.

Accounting both for individual differences in the stress response and the biological concept of homeostasis, McEwen (1998) described in his allostatic load model how stress can affect health, stating that when faced with a stressor, an organism seeks to maintain homeostasis. The body has adaptive systems to achieve this, for example, the hypothalamic-pituitary-adrenal (HPA) axis and the autonomic nervous system (ANS). Allostatic load refers to the costs an organism faces in order to reach allostasis – an essential component of maintaining homeostasis (McEwen, 1998). Detrimental effects of stress on health are explained by an imbalance in these systems, which may result from repeated stress. Furthermore, whereas Cannon (1932) and Selye (1973) do not account for individual differences in the stress response, McEwen (1998) posits that individual differences in stress responses are based on individual genetic makeup, learning history and appraisal processes of a stressor as either threatening or non-threatening.

1.1.1. Physiological stress response

Stress is therefore a psychobiological state that is characterized by not only psychological but also physiological consequences. Accordingly, a multidimensional approach to assess stress is necessary (Nater, Skoluda, & Strahler, 2013). Concerning the physiological stress response, this thesis concentrates on two prominent major stress-sensitive systems in the body that are activated when experiencing stress: the hypothalamic-pituitary-adrenal (HPA) axis and the autonomic nervous system (ANS).

1.1.1.1 Hypothalamic-pituitary-adrenal (HPA) axis

The HPA axis is responsible for the endocrine stress response. When stress is experienced, the HPA axis becomes activated, initiating a cascade of neuroendocrine changes within the body. Starting in the hypothalamus, which forms part of the central nervous system, the corticotropin-releasing hormone (CRH) is released, which affects the anterior pituitary gland. The anterior pituitary gland then releases the adrenocorticotropic hormone (ACTH), which stimulates the release of glucocorticoids, ultimately stimulating the release of cortisol from the adrenal cortex. Cortisol, a glucocorticoid, can be considered an indirect marker for the activity of the HPA axis and has become a widely recognized stress hormone (Hellhammer, Wust, & Kudielka, 2009). Cortisol shows a distinct pattern regarding its reactivity to stress, as peak concentrations of salivary cortisol can be measured approximately 10 to 30 minutes post-stressor (Kirschbaum & Hellhammer, 2000). Furthermore, cortisol shows distinct diurnal variations, with a steep increase in cortisol 30 minutes after awakening (referred to as cortisol awakening response) and a steady decline over the course of the day (Steptoe, 2000). Cortisol can be measured in blood, urine, and saliva, although only salivary cortisol allows the measurement of free, biologically active cortisol. Especially in daily life settings, salivary cortisol is commonly used as an indirect marker for HPA axis activity (Hellhammer et al., 2009). Although there are some dissociations with cortisol in blood or urine as well as with CRH, ACTH, and perceived stress (Hellhammer et al., 2009), measurements of salivary cortisol in daily life show good validity and reliability (Segerstrom, Boggero, Smith, & Sephton, 2014).

1.1.1.2 Autonomic nervous system (ANS)

The autonomic stress response is linked to the activation of the ANS. The experience of stress leads to an activation of the ANS, which can be measured via a range of autonomic markers, such as cardiovascular parameters, skin conductance levels, and breathing rate (Ellis & Thayer, 2010). One recently established marker of ANS activity that can be reliably and validly assessed in saliva is salivary alpha-amylase (Nater & Rohleder, 2009). An advantage of salivary alpha-amylase over other markers of ANS activation is the concurrent measurement of other physiological stress markers, such as salivary cortisol (Rohleder & Nater, 2009). Furthermore, salivary alpha-amylase allows relatively easy sampling in comparison to instruments used for the assessment of other ANS parameters (heart rate, skin conductance) and thus makes salivary alpha-amylase applicable in daily life (Rohleder & Nater, 2009). Salivary alpha-amylase is a salivary enzyme that is produced directly in exocrine salivary glands (Nater & Rohleder, 2009), which has been linked to the activation of the ANS. Thus, it can be considered as a surrogate marker for ANS activation (Nater, La Marca, et al., 2006). Although it shows moderate positive correlations with other indicators of ANS activation, such as cardiovascular parameters and skin conductance levels, these correlations are relatively small (Nater & Rohleder, 2009). Concerning the temporal dynamics of ANS activity relative to a stressor, the ANS reacts immediately to acute stressors (Nater, La Marca, et al., 2006). Salivary alpha-amylase also shows a distinct diurnal pattern, with a decrease within the first 60 minutes after awakening (alpha-amylase awakening response) and a steady increase over the day (Nater, Rohleder, Schlotz, Ehlert, & Kirschbaum, 2007).

1.1.1.3 Rationale for assessing salivary cortisol and salivary alpha-amylase

Subjective stress, HPA axis activity, and ANS activation are all part of the psychobiological stress response. Detrimental effects of stress on health are thought to be mediated by long-term dysfunctions in immune system activity (Glaser & Kiecolt-Glaser, 2005; Godbout & Glaser, 2006). In this regard, the field of psychoneuroendocrinology is interested in exploring bi-directional communication pathways among the central nervous system, the endocrine, and the immune system in an attempt to reveal how disruptions in these interactions can result in immune dysfunction and thus ultimately lead to health consequences (Glaser & Kiecolt-Glaser, 2005; Godbout & Glaser, 2006). Most interestingly, the HPA axis and the ANS are considered the two key pathways that can lead to immune dysregulation (Glaser & Kiecolt-Glaser, 2005; Padgett & Glaser, 2003). In this regard, it is especially stress-related immune dysregulations that can provoke health changes (Glaser & Kiecolt-Glaser, 2005; Godbout & Glaser, 2006). For example, whereas acute stress is associated with short-term enhancing effects on immune system function, chronic stress can have immunosuppressive functions in that stressors can increase the risk for infectious diseases, influence the severity of disease, slow down wound healing, or diminish the strength of immune function (Dhabhar, 2009; Glaser & Kiecolt-Glaser, 2005; Godbout & Glaser, 2006; Segerstrom & Miller, 2004). Especially glucocorticoids (such as cortisol) can have immunosuppressive effects (Glaser & Kiecolt-Glaser, 2005; Padgett & Glaser, 2003). Likewise, catecholamines, which act on the sympathetic nervous system, are associated with modulations of immune system functioning, e.g., including influences on cytokine production (Padgett & Glaser, 2003). Thus, it is the effects of the HPA axis and the ANS on immune function that account for deleterious effects of stress on health (Glaser & Kiecolt-Glaser, 2005). However, markers of immune system activity cannot be as validly assessed in daily life settings. In particular, it remains unclear how immune markers measured in saliva relate to the well-established markers of immune system activity in blood (Slavish, Graham-Engeland, Smyth, & Engeland, 2015). Thus, due to known associations among the HPA axis, ANS, and the immune system, it might be speculated how the activity of the HPA axis and the ANS might ultimately affect immune system activity. Indeed, both salivary cortisol (e.g., Dahlgren, Kecklund, Theorell, & Akerstedt, 2009; Lindfors & Lundberg, 2002) and salivary alpha-amylase (e.g., Granger, Kivlighan, El-Sheikh, Gordis, & Stroud, 2007) have been linked to health-related outcomes. Thus, these two markers allow for studying the physiological underpinnings of the effects of stress on health.

Interestingly, due to the aforementioned different temporal dynamics of cortisol secretion and alpha-amylase activity relative to a stressor, it is unsurprising that subjective stress, salivary alpha-amylase, and salivary cortisol show certain dissociations and one assessment cannot replace the other. In particular, as stress is a multi-faceted phenomenon, it needs to be assessed via a multidimensional approach. Therefore, combining indicators of subjective stress with indicators of HPA axis and ANS activity would appear to be conducive to obtaining a comprehensive impression of the psychobiological stress response. Especially in daily life, multiple assessments per day of salivary cortisol and salivary alpha-amylase allow psychobiological stress to be investigated in its natural habitat.

1.2. Music listening, stress, and health

Music has a long tradition as a therapeutic agent in the context of health (MacDonald et al., 2012b; Mornhinweg, 1992; Raglio & Oasi, 2015), and music therapy has a long history in the assessment of associations between music and health (Hanser, 2011; MacDonald et al., 2012b). However, as music listening is ubiquitous in daily life, the everyday uses of music listening have recently attracted increasing interest (MacDonald et al., 2012b).

Although evidence on health-beneficial effects of music therapy has been reported (Hanser, 2011), evidence on the effects of mere music listening in daily life is scarce (Juslin et al., 2008). Moreover, due to methodological heterogeneities, a common theoretical framework for health beneficial effects of music listening has not yet been found (MacDonald et al., 2012b), and research addressing mechanisms underlying the health-beneficial effects of music listening is still in its infancy (Chanda & Levitin, 2013; Fancourt, Ockelford, & Belai, 2014; Thoma & Nater, 2011). So far, effects of music listening on health have been predominantly examined in clinical and experimental settings (Chanda & Levitin, 2013). In this regard, psychological and physiological effects of music have been found in both clinical and non-clinical samples. It has been suggested that the health-beneficial effects of music listening may be explained by music's ability to exert effects on a neurohormonal level (Chanda & Levitin, 2013; Koelsch, 2010, 2014; Thoma & Nater, 2011). In this regard, particular interest has arisen in music's ability to reduce stress in the context of music and health (Fancourt et al., 2014), with authors hypothesizing that music listening exerts health-beneficial effects through a reduction of psychobiological stress (Thoma & Nater, 2011).

1.2.1. Music listening and stress

Empirical findings from experimental studies point towards a stress-reducing effect of music listening, although inconsistencies are reported across studies (Chanda & Levitin, 2013; Fancourt et al., 2014; Kreutz et al., 2012; Thoma & Nater, 2011). A large proportion of the studies on the stress-reducing effect of music listening were conducted in surgical settings, examining patients. Music listening before (Merakou et al., 2015; Miluk-Kolasa, Matejek, & Stupnicki, 1996), during (Jimenez-Jimenez, Garcia-Escalona, Martin-Lopez, De Vera-Vera, & De Haro, 2013; Koelsch et al., 2011), and after surgery (Nilsson, 2009; Nilsson, Unosson, & Rawal, 2005) was found to be associated with stress-reducing effects. However, the picture is far from complete, as inconsistencies exist with regard to the effects of music listening on physiological parameters (Thoma & Nater, 2011). Moreover, some studies found no beneficial effects of music listening during surgery (Migneault et al., 2004).

In the context of experimental studies investigating healthy participants, music listening before (Thoma et al., 2013) or after (Chafin, Roy, Gerin, & Christenfeld, 2004; Hirokawa & Ohira, 2003; Khalfa, Bella, Roy, Peretz, & Lupien, 2003; Koelsch et al., 2016; Sandstrom & Russo, 2010) a stressful event has been associated with stress-reducing effects. However, similar to the studies conducted in surgical settings, studies in healthy participants have identified differing physiological parameters of stress which are affected by music listening. This is most often argued to be a result of methodological heterogeneities (e.g., selection of music stimuli, selection of study sample), which make it difficult to draw comparisons across studies (Chanda & Levitin, 2013; Fancourt et al., 2014; Koelsch & Jaencke, 2015; Thoma & Nater, 2011). Furthermore, a common understanding and a comprehensive framework for understanding the physiology underlying the stress-reducing effects of music listening are still lacking.

1.2.2. Physiology underlying the stress-reducing effects of music listening

Undoubtedly, music has numerous physiological effects on the human body, although the exact physiological underpinnings of the health-beneficial effects remain to be elucidated. Among others, Altenmüller and Schlaug (2012) suggested that brain plasticity is the key mechanism in mediating effects of music listening on health. In particular, they distinguish short-term from long-term effects regarding the influence of music on the brain. With respect to the short-term effects, music listening has acute effects on various brain regions that are involved in integrating different sensory inputs associated with the music into the complex musical experience. In this regard, Koelsch (2011) proposed a neurocognitive model of serial music processing in the brain, starting with an analysis of acoustic features, followed by processing meaning in music, and potentially leading to music-induced emotions at a later stage. At this later stage of musical processing in the brain, music listening has the capacity to modulate activity in paralimbic and limbic regions of the brain, most prominently in the amygdala, the nucleus accumbens, and the hippocampus (Koelsch, 2010). As the hippocampus and the amygdala are especially involved in the regulation of autonomic, hormonal, and immune system activity, this connection might explain how the effects of music listening can be translated into health-beneficial effects (Koelsch, 2014). Similarly, Thoma and Nater (2011) posited that music has health-beneficial effects through a reduction in psychobiological stress as music influences the HPA axis and the ANS. Thus, music has both acute and long-term effects as according to Altenmüller and Schlaug (2012), long-term effects of music manifest themselves in a change in activity in these core regions modulated by music listening, and long-term connections among these regions arise. Thus, the capacity of music to modulate activity in brain regions involved in the regulation of endocrine and autonomic systems on a cortical and subcortical level might explain beneficial effects of music listening on health (Altenmüller & Schlaug, 2012; Chanda & Levitin, 2013; Koelsch, 2014; Panksepp & Bernatzky, 2002).

Indeed, as noted above, musical experiences are processed in core emotion networks in limbic and paralimbic structures of the brain (Koelsch, 2010, 2014). Interestingly, the HPA axis is regulated by brain structures of the limbic system (e.g., hippocampus, amygdala), and music listening has already been shown to affect HPA axis activity in a plethora of experimental studies (Chanda & Levitin, 2013). However, the findings are inconsistent, as some studies found that music leads to a down-regulation of HPA axis activity (as mirrored by lower cortisol secretion) and other studies found activating effects on HPA axis activity (Thoma & Nater, 2011). The effects of music listening on cortisol were summarized in three recent reviews (Chanda & Levitin, 2013; Fancourt et al., 2014; Kreutz et al., 2012), all of which stated that beneficial effects of relaxing music listening on cortisol can often be found in the expected direction, leading to the conclusion that music affects stress responses at the hormonal level. However, the reviews focused exclusively on experimental studies, as the effects of mere music listening on psychobiological stress in daily life have yet to be examined.

The effects of music listening on the ANS have received probably even more intensive investigation (Ellis & Thayer, 2010; Hodges, 2011; Thoma & Nater, 2011). Here, additionally the brain stem seems to play a particular role in translating the effects of music listening into effects on the ANS. Chanda and Levitin (2013) suggested that music is initially processed at the level of the brain stem, and thus initiates brain stem responses that influence autonomic processes. Therefore, there are many findings on music listening and parameters of the ANS, such as heart rate, heart rate variability, skin conductance (Ellis & Thayer, 2010), but recent research has also investigated the enzyme alpha-amylase (Thoma et al., 2013). Overall, the pattern of results suggests beneficial effects of music listening on parameters of the ANS that are closely associated with characteristics of the music, e.g. rhythm (Bernardi et al., 2009), tempo (Bernardi, Porta, & Sleight, 2006; Egermann, Fernando, Chuen, & McAdams, 2015; Khalfa, Roy, Rainville, Dalla Bella, & Peretz, 2008), and valence and arousal (Dousty, Daneshvar, & Haghjoo, 2011; Iwanaga, Kobayashi, & Kawasaki, 2005; Iwanaga & Moroki, 1999). In this regard, Chanda and Levitin (2013) drew on an evolutionary framework, proposing that the brain stem interprets music as signals associated with survival. Accordingly, the authors interpreted the common finding that energizing music leads to an activation of the ANS as an indication of a fight-or-flight response, whereas relaxing music does not signal danger and thus leads to a decrease in ANS activity. However, this explanation is quite speculative in nature. Thus, Gomez and Danuser (2007) concluded that the features of music which lead to these physiological effects are unknown.

Consequently, a curious gap exists in the literature as to which characteristics are responsible for the stress-reducing effects of music listening. Nevertheless, in order to use music as an efficient and effective means of stress reduction in daily life, an understanding of the drivers of the stress-reducing effects of music listening is essential.

1.2.3. What is stress-reducing about music listening?

The heterogeneous findings on the effects of music listening on psychobiological stress lead to the conclusion that more in-depth knowledge is warranted on which exact characteristics influence the relationship between music listening and psychobiological stress. Indeed, music listening is more than an acoustic event, and when deciding to listen to music in a particular situation, many decisions occur with regard to music selection based on current mood, desired mood, etc. (MacDonald et al., 2012b). Therefore, it is plausible to assume that it is not only music listening per se that exerts stress-reducing effects, but rather that these health-beneficial effects unfold depending on characteristics associated with the music, the situation, and the listener (Juslin et al., 2008).

1.2.3.1 Characteristics of the music

In this thesis, characteristics of the music are defined as both objective properties of the music (e.g., tempo) as well as subjective evaluations of the music (e.g., arousal, liking). Associations between objective characteristics of the music and physiological effects of music listening are consistently reported. In this regard, probably the most four prominent characteristics are: tempo, consonance, timbre (voice), and loudness (Kreutz et al., 2012). Physiological effects of music listening on ANS activity in particular are closely linked to tempo and loudness as objective characteristics of the music, with music exhibiting a slower tempo (Bernardi et al., 2006) and lower loudness (Bernardi et al., 2009) being associated with lower ANS activity.

However, findings on the role of valence and arousal in the stress-reducing effect of music listening, two characteristics of music that have been investigated in a plethora of experimental studies, are inconsistent (Chanda & Levitin, 2013). Whereas the valence of the music (ranging from sad to happy) seems to be particularly associated with HPA axis activity (Thoma & Nater, 2011), findings on the effects of valence on ANS activity are conflicting, with some studies finding associations and others finding little effect on ANS activity (Krabs, Enk, Teich, & Koelsch, 2015). Koelsch (2010) concluded from a review of the literature that the valence of the music is most often associated with modulating activity in the limbic system of the body, which regulates the HPA axis. Thus, music-evoked joy was associated with activity in the hippocampus and hypothalamus, which is involved in the neuroendocrine stress response (Koelsch & Skouras, 2014). The majority of studies found the arousal of the music (ranging from relaxing to energizing) to be associated with ANS activity, with relaxing music decreasing ANS activity and activating music increasing ANS activity (Khalfa, Isabelle, Jean-Pierre, & Manon, 2002). Similarly, the arousal of the music has also been associated with HPA axis activity in both healthy and patient populations (Chanda & Levitin, 2013). However, there are also studies which found no associations (Hodges, 2011).

Taken together, findings on the role of valence and arousal in the stress-reducing effect of music listening are mixed. This is probably due to methodological heterogeneities as observed by Chanda and Levitin (2013), who stated that in many studies, it was unclear how valence and arousal were actually classified (e.g., based on the experimenter or based on the participant). Thus, it is necessary to further elaborate on the role of valence and arousal, especially in daily life, where actual music listening occurs. Nevertheless, to date, no study has investigated the contribution of valence and arousal to the stress-reducing effect of music listening in daily life.

1.2.3.2 Characteristics of the situation

Characteristics of the situation are defined in this thesis as momentary influences on music selection that are shaped by the surroundings of the listener while listening to music. According to Juslin et al. (2008), characteristics of the situation comprise factors such as physical location, activity, presence of others, source of music, and control over choice of music. However, this list seems to be incomplete. Especially with regard to the stress-reducing effect of music listening, the following further factors need to be accounted for. First, listeners might decide to listen to music in daily life for different reasons depending on the situation. Particularly as music listening is often deliberately employed for emotion regulation (van Goethem & Sloboda, 2011), it needs to be assessed why someone listens to music in a particular situation in daily life. Thus, reasons for music listening might be predictive for the stress-reducing effect of music listening. Second, situations in daily life might differ with respect to the appraisal of a situation as stressful, meaning that the success of music for stress reduction purposes might also vary depending on these appraisal processes. Third, social characteristics of the situation might not only concern the presence of others while listening to music; rather, interactions among listeners might also be relevant. In this regard, studying the effects of music listening in a dyadic context seems to be especially relevant, as positive couple interactions have been associated with stress-reducing effects (Ditzen et al., 2007). Thus, the contribution of this thesis is to examine characteristics of the situation that are relevant for the stress-reducing effect of music listening in daily life.

Specifically, the rationale for considering reasons for music listening is based on the empirical evidence from both survey studies and studies set in daily life that relaxation is one of the main reasons for music listening in daily life (Juslin et al., 2008; van Goethem & Sloboda, 2011). For instance, Juslin et al. (2008) were able to show that the beneficial effects of music listening in daily life vary depending on reasons for music listening. Likewise, van Goethem and Sloboda (2011) demonstrated that reasons for music listening are associated with its success in regulating affect. However, it has not yet been tested whether listening to music for the reason of relaxation actually leads to stress reduction.

Additionally, listening situations might vary depending on the appraisal of how stressful the situation is (Juslin et al., 2008). Indeed, there is evidence from the experimental literature that the stress-reducing effect of music listening varies depending on the intensity of stress. In this regard, it was shown that music listening exerts stress-reducing effects only under low to moderate stress (Pelletier, 2004; Thoma et al., 2013). Moreover, Fancourt et al. (2014) suggested that it is necessary to distinguish stress-reducing effects of music listening according to the type of stressor that is employed. Thoma and Nater (2011) also provided arguments for different effects of music listening depending on the type of stressor (operationalized as major vs. minor stressor). However, so far, no study has investigated whether daily life stress of varying intensity (as opposed to experimentally induced stress) affects the stress-reducing impact of music listening.

The consideration of social characteristics of the situation is based on the rationale that beneficial effects of music listening are mediated by inducing neurohormonal changes associated with social affiliation (Chanda & Levitin, 2013; Koelsch, 2014). Indeed, social factors are closely related to health (Uchino, 2006; Uchino, Cacioppo, & Kiecolt-Glaser, 1996), which seems to be mediated by the activity of the HPA axis and the ANS. At the same time, from an evolutionary perspective, music listening is assumed to fulfill social functions (e.g., contact, cooperation, coordination) (Koelsch, 2013).

In this thesis, the presence of others will be considered as one characteristic of the listening situation. In this regard, Chanda and Levitin (2013) argued that the heterogeneities in the empirical findings might be due to lacking information on the social context of the music listening situation. Thus, they called for future studies to rigorously separate whether music is investigated as a solitary activity, a group activity or in a dyadic (therapeutic) context. Interestingly, the presence of others has already been examined in experimental studies, and there is evidence that the effects of music listening vary depending on the presence of others (Egermann et al., 2011; Liljeström, Juslin, & Västfjäll, 2013). Studies focusing on daily life have begun to investigate the presence of others while listening to music (Greasley & Lamont, 2011; Juslin et al., 2008; Sloboda, O'Neill, & Ivaldi, 2001). For instance, Juslin et al. (2008) found more music-evoked positive emotions when listening to music in the presence of others. In the context of music listening and stress, the presence of others has not yet been examined. However, as the presence of others has already been associated with stress-reducing effects (Seeman & McEwen, 1996), it is quite plausible to assume that music listening in the presence of others might enhance this stress-reducing effect.

Expanding the idea of a particular importance of social characteristics of the situation, it might not be the mere presence of any others while listening to music that affects the stress-reducing effect of music listening. Rather, couples might particularly benefit from music listening for stress-reduction purposes. As music is considered an agent of social bonding and affiliation (Clarke, DeNora, & Vuoskoski, 2015; Tarr, Launay, & Dunbar, 2014), which has predominantly been investigated in the context of the formation of friendships and peer groups (e.g., Boer & Abubakar, 2014; Boer et al., 2011), it is of special interest to study the effects of music listening in a dyadic context. Indeed, there is preliminary evidence that in a dyadic context, couples can benefit from music listening for stress reduction purposes (Hanser, Butterfield-Whitcomb, Kawata, & Collins, 2011; Hinman, 2010). In particular, with music being considered a form of non-verbal communication, music listening was found to improve communication in a dyadic context (Botello & Krout, 2008; Hinman, 2010; Körting, Marmé, Verres, & Stammer, 2005). However, as these results were based on caregiver dyads in which one partner was caring for a hospitalized partner, this thesis tests whether music listening is associated with stress-reducing effects in a dyadic context of healthy couples.

1.2.3.3 Characteristics of the person

People might differ in the degree to which they benefit from music listening for stress-reduction purposes based on interindividual differences. For example, there are individual differences in the experience of music-induced chills. Chills were first described by Goldstein (1980), who defined chills in accordance to 'thrills' as 'a subtle nervous tremor caused by intense emotion or excitement (as pleasure, fear, etc.), producing a slight shudder or tingling through the body' (Goldstein, 1980, p. 126). Music-induced chills are associated with emotional peak experiences while listening to music (Panksepp, 1995). The experience of chills is linked to various physiological effects on ANS activity (Benedek & Kaernbach, 2011; Grewe, Nagel, Kopiez, & Altenmüller, 2007) and the brain (Blood

& Zatorre, 2001). In particular, chills are associated with activity in the limbic system (Blood & Zatorre, 2001) thus encouraging the hypothesis that the experience of chills might be associated with the stress-reducing effects of music listening. As there are interindividual differences in the experience of chills, research has begun to investigate the ability to experience music-induced chills as a trait (Grewe et al., 2007; Nusbaum & Silvia, 2011). However, it has not yet been investigated whether the effects of music listening vary depending on the habitual experience of chills, although this might be highly relevant in the context of music listening and stress.

So far, research has focused on interindividual differences in music preferences, which are consistently reported across studies in terms of personality traits within the Big Five framework, especially openness to experience, which has long been investigated in relation to music preferences (Rentfrow & McDonald, 2011). Only recently have studies found that personality characteristics account not only for differences in music preference but also for differences in the perception of music (Rawlings, Barrantes i Vidal, & Furnham, 2000), the reactivity to music (Juslin et al., 2008; Nater, Krebs, & Ehlert, 2005), and the uses of music (Chamorro-Premuzic & Furnham, 2007). Furthermore, research has recently begun to identify personality traits that are specific to music. In this regard, cognitive styles of music listening were coined, accounting for individual differences in the perception and use of music (Kreutz, Schubert, & Mitchell, 2008; Linnemann, Gollwitzer, Kreutz, & Nater, in preparation). Likewise, music-induced chills are also considered an important trait (Grewe et al., 2007).

Thus, in line with this recent development, this thesis aims at investigating interindividual differences in music-related personality traits. Due to the overlap in brain regions involved with the experience of chills and the regulation of the HPA axis, and given the profound effects of chills on the ANS, it was tested whether the habitual experience of chills accounts for interindividual differences in the stress-reducing effect of music listening.

1.2.4. Music listening and health

As outlined above, it has been hypothesized that the health-beneficial effects of music listening are mediated by a reduction in psychobiological stress. Effects of music listening on health have been investigated in numerous experimental studies, covering a wide range of medical and mental health conditions. Music interventions have even been implemented in daily life, with participants being asked to listen to music on a daily basis (Guetin et al., 2012; Hanser et al., 2011; Lai & Good, 2005; Onieva-Zafra, Castro-Sánchez, Matarán-Penarrocha, & Moreno-Lorenzo, 2013; Särkämö et al., 2014; Yang, 2016). The majority of studies point towards beneficial effects, with only a minority failing to find beneficial effects of music listening on health (Mignault Goulet, Moreau, Robitaille, & Peretz, 2012). Of particular interest is the pain-reducing effect of music listening. Pain poses significant challenges to health, as it is associated with a high burden for patients and high costs for society (Breivik, Collett, Ventafridda, Cohen, & Gallacher, 2006). Particular interest in music has arisen in the context of pain, as empirical evidence highlights music listening as a non-pharmacological agent that has no adverse effects and thus presents itself as an attractive adjuvant treatment option for the management of pain (Bernatzky et al., 2012).

1.2.4.1 Music listening and pain

Evidence from experimental studies suggests that music listening is associated with pain-reducing effects (Bernatzky, Presch, Anderson, & Panksepp, 2011; Bernatzky et al., 2012; Mitchell & MacDonald, 2012). The first study on pain-reducing effects of music listening was conducted by Gardner and Licklider (1959), who presented their patients with music while they were undergoing dental treatment. They coined the term 'audioanalgesia', which soon became the focus of many studies. Indeed, patients undergoing surgery were found to report lower pain ratings and ask for less pain medication (Bernatzky et al., 2011, 2012). Healthy participants undergoing pain induction in experimental settings (e.g., by means of heat induction or cold pressor test) showed increased pain tolerance when listening to music (Mitchell & MacDonald, 2006). However, the findings are mixed, and it remains unclear which music is best for pain reduction, e.g. with regard to who had control over choice of music, valence and arousal of the music (Mitchell & MacDonald, 2012). Most importantly, underlying mechanisms are not yet fully understood. It has been discussed that relaxation might explain the pain-reducing effects of music listening, and thus relaxing music is often chosen as stimulus (Mitchell & MacDonald, 2006, 2012). This is indeed a plausible assumption, as core regions in the brain involved in pain perception partly overlap with structures associated with regulating the stress response (Bernatzky et al., 2012). Furthermore, the acknowledgement of the role of individual differences is still in its infancy in the context of the pain-reducing effect of music listening (Bradshaw, Donaldson, Jacobson, Nakamura, & Chapman, 2011), although Good (1996) reported substantial interindividual variation in music-induced analgesia.

In this thesis, a sample of female patients with fibromyalgia syndrome (FMS), a chronic condition characterized by widespread pain (Woltman, Feldstain, & Rocchi, 2012), will be examined in one study. Stress has been discussed as a candidate to explain the manifestation of pain symptoms in FMS, as patients with FMS already show alterations in stress-sensitive systems in the body, that is dysfunctions in HPA axis (Tak et al., 2011) as well as in ANS functioning (Martinez-Lavin, 2002). As outlined by Ellis and Thayer

(2010), it is of utmost importance to understand effects of music in the context of already distorted stress systems, e.g. autonomic dysfunction. Furthermore, as most of the studies on music and pain were conducted in experimental settings, Mitchell and MacDonald (2012) called for the effects of music listening to be studied in ecologically valid settings, as the pain is experienced in daily life. Following Good (1996), it is necessary to assess individual differences in the pain-reducing effect of music listening. Thus, the role of the habitual experience of music-induced chills is examined as a potential moderator for the pain-reducing effect of music listening.

1.2.5. A framework for assessing health-beneficial effects of music listening mediated by a psychobiological reduction in stress

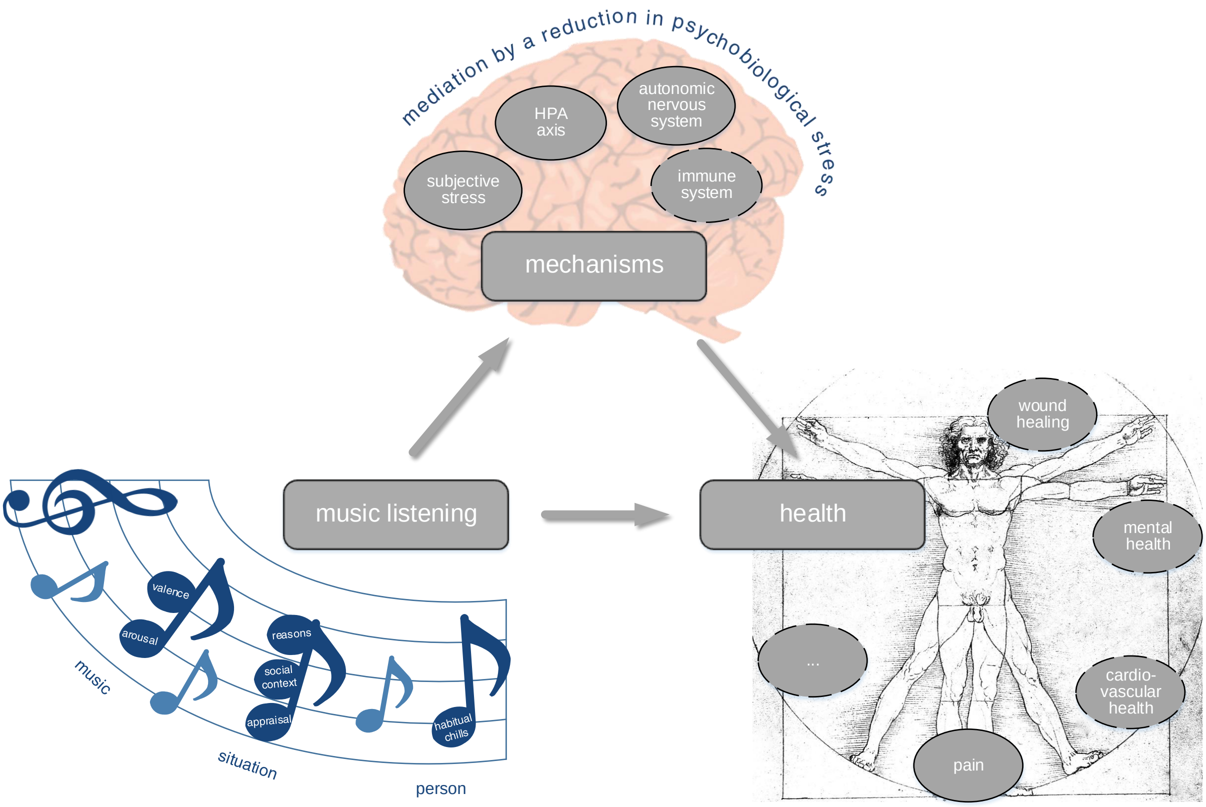
In order to shed further light on the stress-reducing effect of music listening, the present thesis proposes a framework which reviews the aforementioned characteristics of the music, characteristics of the situation, and characteristics of the listener to explain health-beneficial effects of music listening that are assumed to be mediated by a reduction in psychobiological stress (Figure 1.1). Here, the focus is on valence and arousal (representing characteristics of the music), reasons for music listening, social context, and appraisal of a situation as stressful (representing characteristics of the situation), and habitual experience of music-induced chills (representing characteristics of the person).

1.3. Limitations and shortcomings in current research

First, although music listening is an activity of daily life, so far, most of the research investigating its beneficial effects has been conducted in the constraints of experimental studies in a laboratory. Thus, studies investigated one artificial music listening situation, with music listening employed before, during, or after a stressful event. Although these studies are high in internal validity, it is unclear whether their results can be transferred to daily life. However, as music listening is an activity of daily life, it is of utmost importance to study its effect in the natural habitat of the participants, with high ecological validity, while they are going about their daily routine.

Second, experimental studies have most often focused on one characteristic of the music listening behavior, e.g. by comparing self-chosen music to experimenter-selected music. However, music listening behavior in daily life is far more complex. As described by MacDonald et al. (2012b), the music listener has to take many voluntary and involuntary decisions when listening to music in one particular situation. Thus, it is necessary to

Figure 1.1: Framework for assessing health-beneficial effects of music listening mediated by a psychobiological reduction in stress



Annotations: HPA axis: hypothalamic-pituitary-adrenal axis; reasons: reasons for music listening (relaxation, distraction, activation, reducing boredom); appraisal: appraisal of a situation as stressful; habitual chills: habitual experience of music-induced chill; dashed lines refer to variables not assessed in this thesis

examine the holistic music listening behavior by considering characteristics of the music, characteristics of the situation, and characteristics of the person in order to understand what is stress-reducing about music listening in daily life.

Third, concerning these beneficial effects of music listening in daily life, the yet limited number of studies (Greasley & Lamont, 2011; Juslin et al., 2008; Randall et al., 2014; van Goethem & Sloboda, 2011) relied on subjective self-reports, without explicitly asking about stress. However, in order to understand mechanisms underlying the stress-reducing effect of music listening in daily life, it is necessary to investigate effects of music listening on the human body in daily life, e.g. by means of assessing psychobiological stress, and thus gather a more comprehensive assessment of stress.

1.4. Summary and research aims

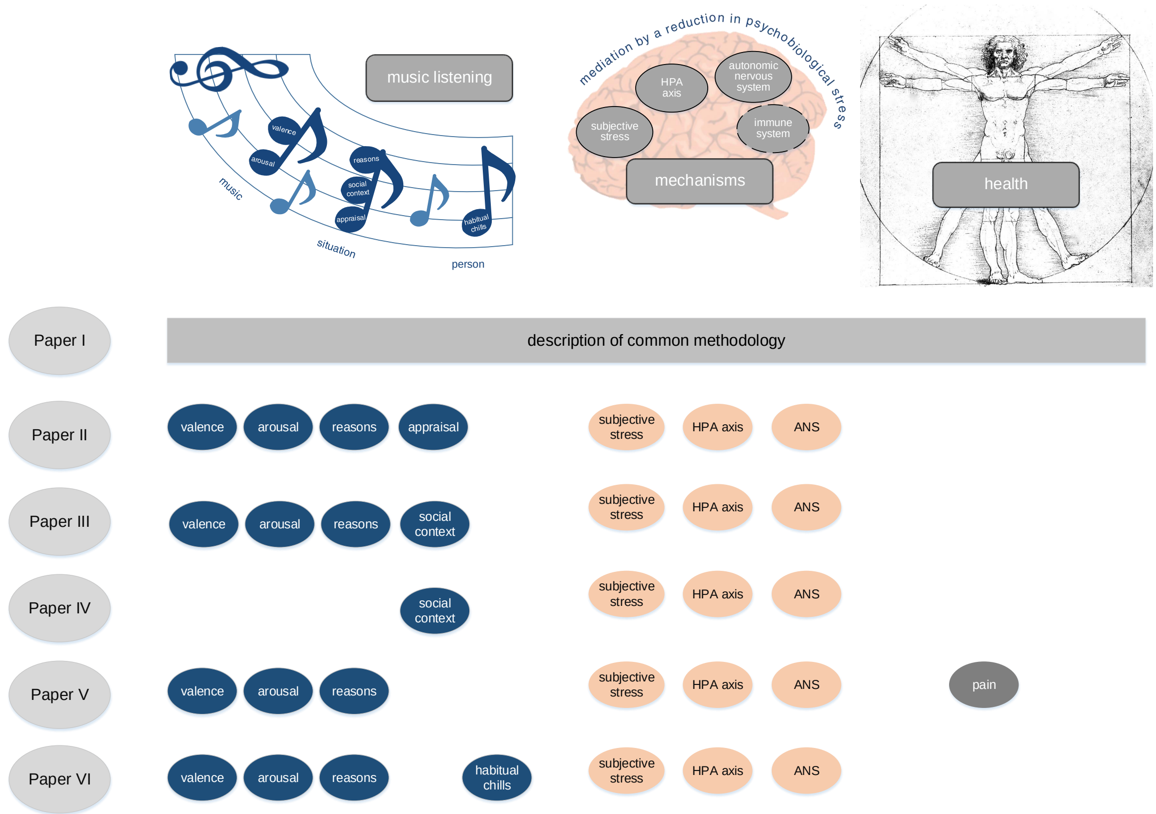
Stress is a common experience of daily life that can lead to diminished health. Interventions targeting stress in daily life are necessary. Music listening is a popular, cost-effective, and easily accessible activity of daily life. Indeed, music listening has been used in a therapeutic context for decades, and research has recently started to investigate effects of music listening in daily life. Although there is preliminary evidence of a stress-reducing effect of music listening in daily life, there are many discrepant findings in the literature, leaving many questions unanswered. Consequently, several important pieces of the puzzle explaining health-beneficial effects of music listening in daily life remain to be found regarding what it is that is stress-reducing about music listening and what psychobiological mechanisms underlie this stress-reducing effect. However, as it is hypothesized that the health-beneficial effects of music listening are mediated by a reduction in psychobiological stress, it is of great importance to understand the exact nature of the stress-reducing effects of music listening.

The overall objective of this thesis is to unravel the stress-reducing effect of music listening in daily life and thus investigate psychobiological mechanisms underlying this stress-reducing effect of music listening in daily life by means of a series of ambulatory assessment studies. In particular, the first research goal addresses the question whether music listening in daily life is associated with psychobiological stress. The second research goal addresses the contribution of characteristics of the music, characteristics of the situation, and characteristics of the person to this stress-reducing effect. The third research goal is to test whether a potentially stress-reducing effect on psychobiological measures of stress mediates the pain-reducing effects of music listening.

This thesis comprises six papers (Figure 1.2). The first paper is methodological in nature and provides a protocol for assessing the effects of music listening on psychobiological stress in daily life (Linnemann, Strahler, & Nater, in revision). Subsequently, five papers covering four ambulatory assessment studies are presented. Thus, in the second paper (Linnemann, Ditzen, Strahler, Doerr, & Nater, 2015), mechanisms underlying the stress-reducing effect of music listening are investigated with regard to a) characteristics of the music (e.g., valence and arousal of the music) and b) characteristics of the situation (e.g., appraisal of situation as stressful, reasons for music listening). In the third paper (Linnemann, Strahler, & Nater, accepted), it is tested whether the stress-reducing effect of music listening varies depending on social characteristics of the listening situation (here: presence of others while listening to music). The aim of the fourth paper (Linnemann, Nater, Spoerri, Ehlert, & Ditzen, in preparation) is to further investigate the role of social characteristics of the listening situation by investigating the stress-reducing effect of music listening in a dyadic context examining couples in their daily life. The fifth paper (Linnemann, Kappert, et al., 2015) investigates a clinical sample, namely female patients with fibromyalgia syndrome (FMS) – a chronic pain condition. It is tested whether pain-reducing effects of music listening are mediated by a reduction in psychobiological stress. In a more detailed follow-up analysis, paper six (Linnemann, Thierschmidt, & Nater, in press) examines whether characteristics of the person account for interindividual differences in the ability to benefit from music listening for stress reduction purposes.

Two of these papers (II, V) were published in 2015. Paper VI is in press. Paper III is accepted. Paper I is currently under revision. Paper IV is in preparation. It should be noted that some results from the study presented in paper II have already been reported in my Diploma thesis. However, the results presented reach beyond the scope of my Diploma thesis, as my PhD thesis uses a novel statistical approach and analyzes physiological parameters of stress.

Figure 1.2: Overview of papers



Annotations: HPA axis: hypothalamic-pituitary-adrenal axis; ANS: autonomic nervous system; reasons: reasons for music listening (relaxation, distraction, activation, reducing boredom); appraisal: appraisal of a situation as stressful; habitual chills: habitual experience of music-induced chills; dashed lines refer to variables not assessed in this thesis

2. Summary of empirical studies

All studies presented in this thesis were designed as ambulatory assessment studies, each focusing on a different aspect of the theoretical framework depicted in Figure 1.1. All studies comprise different study populations. Participants were screened via a telephone-based interview for inclusion criteria (which cover criteria associated with age, body mass index (BMI), medication, physical health conditions, and mental health conditions). Upon inclusion, all participants received a pre-programmed iPod touch that required them to answer items four (Paper II, IV) or five (Paper III, V, VI) times per day (spanning a period from awakening till bedtime) for the duration of five, seven, ten, or fourteen consecutive days, respectively. Items covered subjective stress, stating 'At this moment, I feel stressed', which could be answered on a five-point Likert scale ranging from 'not at all' (0) to 'very much' (4). Items on music listening behavior asked whether music listening had occurred since the last assessment, and could be answered with either yes or no. If music listening was reported, in studies reported in papers II, III, V, and VI, subsequent items asked for the perceived valence (on a visual analogue scale ranging from 'sad' (0) to 'happy' (100)) and perceived arousal (on a visual analogue scale ranging from 'relaxing' (0) to 'energizing' (100)) of the music, as well as for reasons for music listening (relaxation, activation, distraction, reducing boredom). At each assessment, participants were asked to provide a saliva sample for the later analysis of salivary cortisol as a marker for HPA axis activity and salivary alpha-amylase as a marker for ANS activity. All analyses are based on two-level hierarchical linear modeling (HLM) (Raudenbush, Bryk, & Congdon, 2004) due to the nested structure of the data, as multiple assessments per day are nested within persons. Using HLM, both unconditional and conditional models were specified. A representative formula for assessing the effects of reasons for music listening on salivary cortisol secretion is depicted here:

Unconditional model:

$$\text{Salivary cortisol}_{ij} = \gamma_{00} + \gamma_{01} \cdot \text{gender}_j + \gamma_{02} \cdot \text{BMI}_j + \gamma_{10} \cdot \text{time of day}_i + u_{0j} + r_{ij}$$

Conditional model:

$$\begin{aligned}\text{Salivary cortisol}_{ij} = {} & \gamma_{00} + \gamma_{01} \cdot \text{gender}_j + \gamma_{02} \cdot \text{BMI}_j + \gamma_{10} \cdot \text{time of day}_{ij} \\ & + \gamma_{30} \cdot \text{relaxation}_{ij} + \gamma_{40} \cdot \text{activation}_{ij} + \gamma_{50} \cdot \text{distraction}_{ij} \\ & + \gamma_{60} \cdot \text{reducing boredom}_{ij} + u_{0j} + r_{ij}\end{aligned}$$

Analyses controlled for time of day, BMI, and gender where appropriate. The comparison between the conditional and unconditional model was undertaken by means of χ^2 square statistics, which compares the reduction in deviance as a measure of model fit.

2.1. Paper I – Assessing the effects of music listening on psychobiological stress in daily life

As summarized in 1.2.1, various experimental studies have provided empirical evidence for a stress-reducing effect of music listening. However, the findings from these studies are restricted to laboratory contexts. In particular, as laboratory studies most often only investigate one single music listening situation in an artificial setting, it remains unknown whether music listening exerts its stress-reducing effects beyond the scope of experimental studies. As music listening is a popular activity of daily life, it is of utmost importance to study the effects of music listening on psychobiological stress in an everyday life setting. In daily life, there are no artificial constraints on the music listening behavior of the participants. Instead, ambulatory assessment studies allow relationships between music listening and stress to be investigated while participants are going about their daily routine.

In the context of music listening and stress, so far, no study has investigated the effects of music listening on psychobiological stress. Rather, studies conducted to date have relied on subjective self-reports on well-being (Juslin et al., 2008; Sloboda et al., 2001; van Goethem & Sloboda, 2011). Thus, based on recommendations from the vast literature on ambulatory assessment studies (Conner & Lehman, 2012; Kudielka, Gierens, Hellhammer, Wust, & Schlotz, 2012; Smyth & Stone, 2003; Wilhelm, Perrez, & Pawlik, 2012), a protocol for assessing the effects of music listening on psychobiological stress is developed, spanning from research design to statistical analyses on the assessment of effects of music listening on psychobiological stress in daily life. Thus, the protocol provided in this paper serves as common methodological foundation for all ensuing studies.This paper is currently under revision as it was submitted to the Journal of Visualized Experiments. Upon publication it will be complemented by a video that visualizes all relevant and essential steps of the protocol.

2.2. Paper II – Music listening as a means of stress reduction in daily life

In this study, the nature of a potentially stress-reducing effect of music listening in daily life was examined considering both subjective as well as physiological markers of stress.

More specifically, it was tested whether music listening exerts a stress-reducing effect and if so, the contribution of characteristics of the music and characteristics of the situation were examined in terms of their relation to the stress-reducing effect of music listening in daily life. By means of assessing physiological markers of stress, mechanisms underlying the stress-reducing effect of music listening were investigated.

Methods A total of 55 healthy participants were examined twice – once at the beginning of the semester (hereafter referred to as control condition) and once at the end of semester (hereafter referred to as exam condition). For the duration of five consecutive days during each condition, participants were asked to answer questions on stress and music listening behavior four times per day (10.00h, 14.00h, 18.00h, 21.00h). Please note that only a sub-sample (n = 25) was asked to provide a saliva sample at each assessment for two consecutive days during each condition for the later analysis of salivary cortisol and salivary alpha-amylase.

Results Three main results emerged from this study: First, mere music listening was associated with lower subjective stress, but not with physiological markers of stress. Second, especially characteristics of the situation (here: reasons for music listening and appraisal of situation as stressful) were closely associated with stress, as music listening for the reason of relaxation was linked to lower subjective stress and lower salivary cortisol secretion. Furthermore, music listening was stress-reducing during the control condition, but not during the exam condition. Third, music listening affected the stress-sensitive systems in the body differentially: Whereas the arousal of the music was associated with ANS activity, reasons for music listening affected HPA axis activity.

Discussion The findings indicated that music listening has stress-reducing effects. However, the stress-reducing effects of music listening per se were limited. Especially characteristics of the situation (such as the reasons for listening to music, appraisal of situation as stressful) mainly contributed to this effect. Interestingly, so far, the literature suggests a relevant role of valence and arousal, with particularly music low in arousal being associated with stress-reducing effects (see chapter 1.2.3.1). However, in this study, it was music that was specifically listened to for the reason of relaxation that was associated with a stress-reducing effect, independently of valence and arousal. Furthermore, music listening differentially affected the physiological stress systems, potentially leading to the conclusion that different aspects of the music listening situation are associated with different aspects of the psychobiological stress response.

To conclude, this study showed that it is not music listening per se that predominantly exerts stress-reducing effects. Rather, especially characteristics of the situation, such as reasons for music listening and appraisal of situations as stressful, affect the stress-reducing effect of music listening in daily life.

2.3. Paper III – The stress-reducing effect of music listening varies depending on the social context

The study presented in paper II revealed that especially characteristics of the situation are associated with the stress-reducing effect of music listening. As music listening is closely linked to social functions from an evolutionary perspective (Hargreaves & North, 1999; Koelsch, 2013) and social contact is associated with a stress-reducing effect (Seeman & McEwen, 1996), paper III aimed at broadening knowledge on how social characteristics of the situation influence the stress-reducing effect of music listening in daily life. More specifically, the role of the social context of the listening situation (here: the presence of others while listening to music) on the stress-reducing effect of music listening in daily life was examined. As it is known from the stress literature that the presence of others is associated with attenuated stress system activity (Seeman & McEwen, 1996), it was tested whether the stress-reducing effect of music listening is enhanced depending on social characteristics of the situation. Thus, by means of both subjective indicators for stress and physiological markers of stress, mechanisms underlying the potential stress-reducing effect when listening to music in the presence of others were investigated.

Methods A total of 53 healthy participants responded to questions on music listening, presence of others, and stress five times per day (30 minutes after awakening, 11.00h, 14.00h, 18.00h, 21.00h) for the duration of seven consecutive days. Each assessment was completed by the collection of a saliva sample for the later analysis of salivary cortisol and salivary alpha-amylase.

Results Three main results were found in this study: First, music listening per se was not associated with any parameter of stress. Second, when listening to music in the presence of others, lower subjective stress levels, lower secretion of salivary cortisol, and higher activity of salivary alpha-amylase were observed, independent of the reason for music listening. Third, when solitary music listening was reported, music listening was associated with lower subjective stress levels when it was listened to for the reason of relaxation.

Discussion The stress-reducing effect of music listening varied depending on the presence of others while listening to music. When listening to music in the presence of others, contrary effects on HPA axis and ANS activity were observed. Whereas a down-regulation of HPA axis took place, an activation of the ANS was found. Thus, differential effects of music listening in the presence of others on psychobiological stress were found. This might be reconciled by the suggestion that music listening in the presence of others might be activating, as interactions among the listeners might take place, leading to activations of the ANS. At the same time, music listening (probably as background activity while engaging in interactions with others) leads to a down-regulation of HPA axis activity possibly due to social functions of music listening, e.g., it might increase feelings of togetherness. Furthermore, when listening to music alone, reasons for music listening become relevant and only music that was listened to for the reason of relaxation is associated with stress reduction. Thus, music listening might fulfill different functions depending in the social context. When listening to music alone, deliberate music listening for the reason of relaxation is helpful for stress reduction purposes, whereas in the presence of others, music listening exerts effects on physiological stress systems independent of a deliberate engagement with the music.

In sum, paper III demonstrated the importance of social characteristics of the situation for the stress-reducing effects of listening to music in daily life. Thus, the presence of others while listening to music seems to be an important contributor to the effects of music listening in daily life.

2.4. Paper IV – Effects of music listening on couple interaction and stress in everyday life

The studies presented in papers II and III revealed that the stress-reducing effect of music listening in daily life seems to depend considerably on characteristics of the situation, especially on the social environment. This seems plausible as social support is assumed to buffer the detrimental effects of stress on health (Cohen & Wills, 1985), and even the mere presence of others was related to stress-reducing effects (Kirschbaum, Klauer, Filipp, & Hellhammer, 1995). Close social relationships are associated with stress-reducing effects as well (Holt-Lunstad, Smith, & Layton, 2010). Being in a couple seems to beneficially affect health (Johnson, Backlund, Sorlie, & Loveless, 2000). At the same time, stress in couples can be harmful, as due to stress crossover, partners become affected by each others' stress levels (Neff & Karney, 2007). Therefore, interventions that address stress in couples are necessary. Positive couple interactions have been previously associated with stress-reducing effects in couples (Ditzen et al., 2007). Furthermore, there is evidence that music listening has positive effects on couple interaction, providing a hint that music may act as an important facilitator for communication and connection in couples (Botello & Krout, 2008; Chavin, 2002; Hinman, 2010; Körting et al., 2005). Moreover, studies show that music in couples not only improves communication skills, but also leads to relaxation (Hanser et al., 2011; Hinman, 2010). Due to the stress-reducing effects of music listening, which are strongly associated with social characteristics of the situation, we investigated whether music listening improves couple interaction and affects psychobiological stress in couples.

Methods Forty healthy couples were examined for five consecutive days in their daily life. Both partners received an iPod touch and were asked to complete questions on their subjective stress level, contact with their partner since the last assessment, and music listening behavior five times per day (30, 150, 480, 720 minutes after awakening, and directly before going to bed). Additionally, at six assessments per day, both partners provided saliva samples. Due to the dyadic data structure, hierarchical linear modeling was performed in accordance with Bolger and Laurenceau (2013).

Results Music listening affected both the occurence and the quality of couple interaction, but only for women: they reported more contact with their partner after having listened to music, but perceived the contact with their partner as more negative when their partner had listened to music. Concerning the stress-reducing effects of music listening, gender differences were found with music listening affecting stress-sensitive systems in the body differentially in females and males. The secretion of salivary cortisol was lowest for females and males if the female partner listened to music. By contrast, the activity of salivary alpha-amylase was highest for men when they themselves or their female partner had listened to music. However, the more similar music preferences were within a dyad, the lower was males' activity of salivary alpha-amylase after their female partner had listened to music.

Discussion Two main results were found in this paper: First, gender differences in effects of music listening on couple interaction and stress were found. In line with the tend-and-befriend hypothesis (Taylor et al., 2000), women seemed to benefit from social functions of music listening in that they engaged in contact with their partner after having listened to music and they experienced less stress after having listened to music. In line with findings from experimental studies (Nater, Abbruzzese, Krebs, & Ehlert, 2006), gender differences concerning psychophysiological effects of music listening were found. Here, especially women seemed to benefit from music listening in daily life for stress reduction purposes. Gender differences in psychophysiological reactivity to music might be attributable to different music preferences or different reasons for music listening, with females engaging more in music listening for stress reduction purposes (an effect that was transferred to their male partner). Males, on the other hand, seemed to benefit from music for reasons of activation. Second, a co-regulation within dyads took place. Although women and men reacted differentially to music when they themselves listened to music, the effect was transferred to their partner.

2.5. Paper V - The effects of music listening on pain and stress in the daily life of patients with fibromyalgia syndrome

The studies presented in papers II to IV provided evidence for a stress-reducing effect of music listening in daily life, with music listening being associated with both subjective and physiological markers of stress. This study aimed to investigate whether the health-beneficial effects of music listening are mediated by a psychobiological reduction in stress. Thus, the potentially pain-reducing effect of music listening was examined in a sample of female patients with fibromyalgia syndrome (FMS).

Methods A total of 30 women meeting the Fibromyalgia Research Criteria (Wolfe et al., 2011) were examined for 14 consecutive days in their daily life. Each day, participants were asked to answer items on pain (pain intensity, control over pain), stress, and music listening (valence and arousal, reasons for music listening) five times per day (30 minutes after awakening, 11.00h, 14.00h, 18.00h, 21.00h). At each assessment, participants provided a saliva sample for the later analysis of salivary cortisol and salivary alpha-amylase.

Results Four main results emerged from this study: First, music listening per se was neither associated with pain nor with stress. Second, the valence of the music and reasons for music listening were associated with control over pain: Music that was rated as positive in valence was associated with increases in control over pain, as was music that was listened to for the reason of relaxation or activation. Further, music that was listened to for the reason of activation was associated with lower pain intensity. Third, interindividual differences emerged, with those patients who listened to music more often benefitting more from music for pain reduction purposes. Fourth, the effects of music listening on pain were not mediated by biomarkers of stress-responsive systems in the body.

Discussion Music listening in daily life had health-beneficial effects insofar as it improved perceived control over pain in female patients with fibromyalgia syndrome. Therefore, mere music listening has the potential to improve symptom control in chronic pain patients when it is positive in valence or is specifically listened to for the reason of relaxation or activation. Music listening did not affect stress, neither subjectively nor physiologically in this study. Consequently, the health-beneficial effect of music listening in this sample of female patients with FMS was not mediated by a reduction in psychobiological stress. This could be due to already distorted stress system functioning in this patient population (Martinez-Lavin, 2002; Tak et al., 2009). In healthy populations, mere music listening might be sufficient for stress reduction purposes, but in already impaired patient populations, a more intensive engagement with music (i.e., collective singing or music-making) rather than mere music listening in daily life might be warranted.

2.6. Paper VI - The influence of the habitual experience of music-induced chills on the stress-reducing effect of music listening in daily life [Der Einfluss des habituellen Chill-Erlebens auf die stress-reduzierende Wirkung von Musikhören im Alltag]

In paper V, mere music listening was not associated with any parameters of stress. However, interindividual differences emerged concerning the pain-reducing effect of music listening. Thus, here, in a more detailed follow-up analysis, the role of interindividual differences in a potentially stress-reducing effect of music listening was examined in female patients with FMS. More specifically, it was tested whether the habitual experience of music-induced chills is associated with a stress-reducing effect of music listening. Chills might play an important role in this context, as the experience of music-induced chills is associated with intensive emotional experiences when consuming music (Panksepp, 1995). Physiological correlates of music-induced chills show that the experience of chills is associated with activation of the ANS (Benedek & Kaernbach, 2011; Grewe, Kopiez, & Altenmüller, 2009; Grewe et al., 2007) and with activity in limbic brain regions (Blood & Zatorre, 2001). Thus, two intersting overlaps in processing of music-induced chills and activity in stress-sensitive systems exist: First, limbic brain regions are involved in processing music-induced chills and in regulating the HPA axis. Second, music-induced chills are associated with ANS activity. Therefore, it was hypothesized that the ability to experience music-induced chills is associated with the stress-reducing effect of music listening in daily life.

Methods In addition to the methods described concerning paper V, participants were asked to fill out the music preference questionnaire (MPQ; Nater et al., 2005) once online. The MPQ comprises, among other things, items on the habitual experience of music-induced chills with regard to both frequency and intensity of music-induced chills.

Results The stress-reducing effect of music listening varied depending on the habitual experience of music-induced chills, the perceived arousal of the music, and depending on the reasons for music listening. In this regard, three main results emerged from these analyses. First, the more intense the experiences of music-induced chills were reported to be, these participants showed higher salivary alpha-amylase activity after listening to music. Second, subjective stress ratings were lowest when participants who reported a lower frequency of music-induced chills listened to music with a low perceived arousal, whereas subjective stress ratings were highest when participants with a higher frequency of music-induced chills listened to music with a low perceived arousal. Third, the secretion of salivary cortisol was lowest in participants with higher frequency of music-induced chills when they listened to music for the reason of relaxation.

Discussion Music listening per se was not associated with a stress-reducing effect for participants with more frequent and more intense habitual experiences of chills. Rather, music listening was associated with activating effects in this particular sample. As evidence from the laboratory shows that the experience of chills is associated with an activation of the ANS, it might be plausible to assume that participants who experience habitual chills are more inclined to react to music with activation. Further, music that was high in arousal was associated with stress-reducing effects in participants with a higher frequency of music-induced chills. Thus, it is possible that people with higher frequency of music-induced chills have a preference for music with a higher arousal. When considering reasons for music listening, a stress-reducing effect of music listening was linked to the habitual experience of music-induced chills, which again emphasizes the importance of reasons for music listening for a stress-reducing effect of music listening. Thus, interindividual differences, the percevied arousal of the music, and reasons for music listening need to be kept in mind when designing interventions using music listening as stress management strategy in female patients with FMS.

3. Discussion

3.1. Summary of results

This thesis aimed at investigating psychobiological mechanisms underlying the stress-reducing effect of music listening in daily life. By means of a series of ambulatory assessment studies, the nature of this beneficial effect of music listening was explored by considering characteristics of the music, characteristics of the listening situation, and characteristics of the person with regard to both psychological and physiological markers of stress.

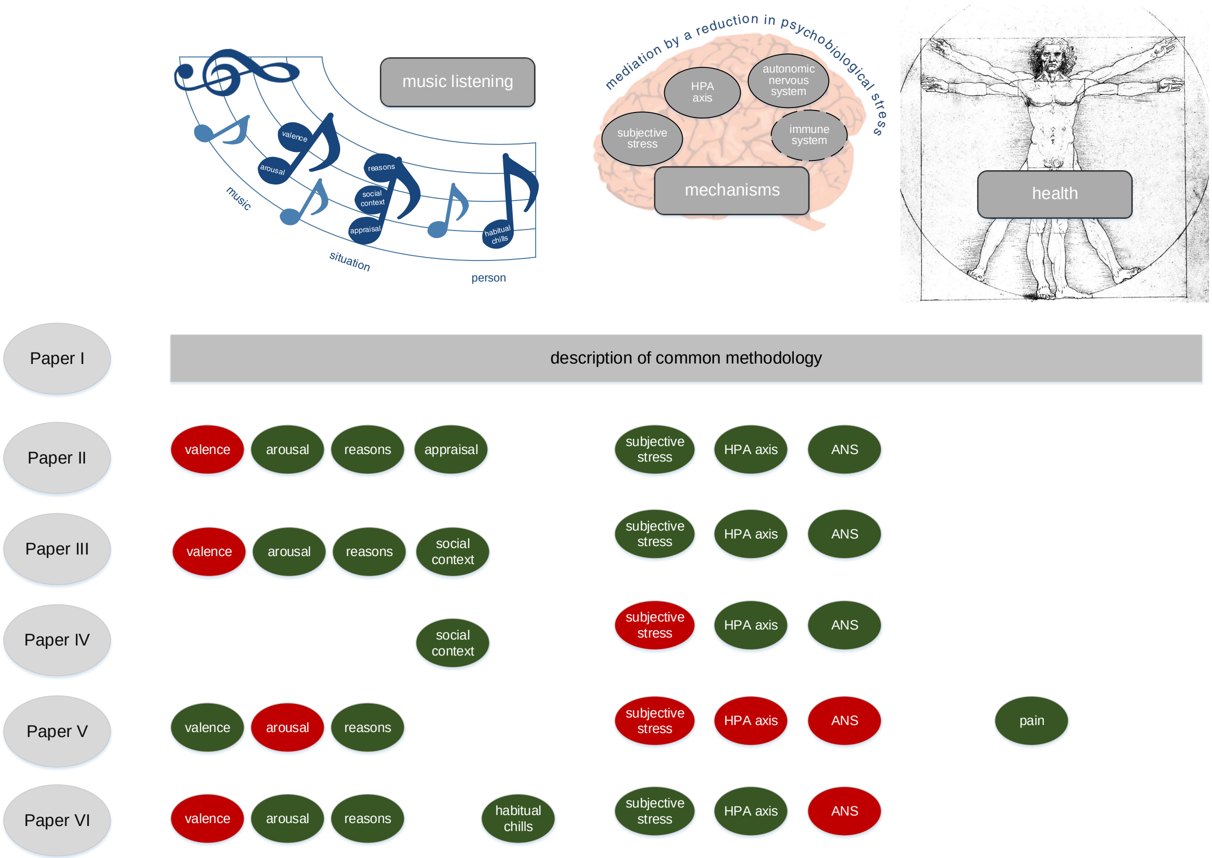
The studies presented in papers II to VI consistently showed that music listening per se has limited or even no stress-reducing effects. Rather, characteristics of the music (here: perceived arousal of the music), characteristics of the situation (here: reasons for music listening, presence of others, interaction with romantic partner, appraisal of situation as stressful), and characteristics of the person (here: habitual experience of music-induced chills) contribute to the nature of the stress-reducing effect of music listening. Concerning underlying physiological mechanisms, music listening differentially affects stress-sensitive systems in the body: Characteristics of the music are associated with ANS activity, whereas reasons for music listening are associated with HPA axis activity. The presence of others is associated with both, but with contrasting effects. In a patient population, the health-beneficial effect of music listening was not mediated by a reduction in psychobiological stress. However, in this patient population characteristics of the person accounted for interindividual differences in the stress-reducing effect of music listening.

3.2. Integration

3.2.1. Music listening as a means of stress reduction in daily life?

MacDonald et al. (2012b) posited that a deliberate engagement with music is the prerequisite for benefitting from music listening. This idea is mirrored in the results of the aforementioned ambulatory assessment studies. It was not music listening per se that had positive effects. Rather, especially reasons for music listening were associated with this effect. In this regard, Riganello, Cortese, Arcuri, Quintieri, and Dolce (2015) suggested

Figure 3.1: Summary of results



Annotations: HPA axis: hypothalamic-pituitary-adrenal axis; ANS: autonomic nervous system; reasons: reasons for music listening (relaxation, distraction, activation, reducing boredom); appraisal: appraisal of a situation as stressful; habitual chills: habitual experience of music-induced chills; green: significant association was found; red: no association was found

that daily experiences with music create expectancies in the listener, with consequences when these expectations are met or not. This idea fits well with our data, as it appears plausible to assume that a stress-reducing effect might be explained by repeated experiences of stress-reducing effects of music that was specifically listened to for the reason of relaxation. However, characteristics of the music also contribute to the stress-reducing effect, with music which is low in arousal being associated with decreased ANS activity. Moreover, individual differences, that is gender differences in the effects of music listening (as they were found in paper IV) and differences based on the habitual experience of chills (as they were found in paper VI) account for differences in the stress-reducing effect of music listening in daily life. Thus, in addition to characteristics of the music, factors such as individual learning history, past experiences with music listening and expectations about the effects of music listening might shape the effects of music listening in daily life. In this regard, Koelsch (2010) stressed the importance of individualized music, as different people will need different music in order to draw a beneficial effect from it. Koelsch (2010) provided the example that patients suffering from depression will need different music than patients suffering from Parkinson's Disease due to different mechanisms underlying these two conditions. This idea of individualized, custom-tailored music was also elaborated by Mitchell and MacDonald (2008), who posited that music is made functionally equivalent by the listener, meaning that music fulfills specific goals as intended by the listener. As music in daily life has been used intuitively so far, this thesis contributes empirical evidence on how to employ music for stress reduction purposes.

Despite a deliberate use of music, music listening was also associated with stress-reducing effects when it occurred in a social context. When listening to music in the presence of others, it is likely that music acts as background activity rather than being in the focus of attention. Consequently, music listening can have stress-reducing effects across different situations with different characteristics of the music and characteristics of the person contributing to this effect.

To sum up, be it deliberate music listening or music listening in the presence of others, music listening has stress-reducing effects based on characteristics of the music, the situation, and the person. Fancourt et al. (2014) posited that the effects of music will vary enormously depending on how it is employed. Thus, there is no common stress-reducing effect. Rather, interactions among all of these factors need to be kept in mind when using music for stress reduction purposes.

3.2.2. Psychobiological mechanisms underlying this stress-reducing effect

All studies presented in papers II to VI provided evidence that different characteristics of the music, the situation, and the person differentially affected the stress-sensitive systems in the body. The pattern of results supports the notion that different stages of processing music in the brain co-vary with different stress-sensitive systems in the body. Interestingly, characteristics of the music (here: perceived arousal of the music) were associated with salivary alpha-amylase. This is in line with Koelsch (2011), who posited that the early analysis of acoustic features of the music co-varies with autonomic responses. Indeed, the ANS is associated with immediate reactions to stress (in comparison to HPA axis activity, which shows a latency in reacting to stress). Interestingly, reasons for music listening (here: relaxation) were associated with HPA axis activity. This could be interpreted through the theory within the model of Koelsch (2011) that music-induced emotions are processed at a later stage and thus affect HPA axis activity.

This idea of different temporal dynamics reflecting different influences of music listening on stress-sensitive systems in the body can reconcile the arousing effects of the presence of others concerning ANS activity and the relaxing effects concerning HPA axis activity. Thus, being in the presence of others might induce activations due to immediate interactions with other persons. With evaluative processes taking place at a later stage of music processing (Koelsch, 2011), HPA axis activity might be decreased due to a pronounced feeling of affiliation, leading to stress-reducing effects. Thus, as HPA axis and ANS activity were concomitantly measured in this study, these activating and relaxing effects were observed but they may reflect different stages of musical processing.

In this regard, Koelsch (2014) stressed the role of music-induced emotions and posited that music-induced emotions are a prerequisite for modulating activity in paralimbic and limbic brain structures, thus stating that it is these music-induced emotions that are involved in evolutionary adaptive neuroaffective mechanisms. Therefore, it might be plausible to assume that characteristics of the music have immediate effects on the ANS, whereas the more complex analysis of the music leads to stress-reducing effects by modulating limbic and paralimbic regions in the brain. Most interestingly, as in the studies presented here the effects of music listening on stress were captured in a time-delayed manner, with music items covering music listening since the last assessment, the results point towards persistent effects of music listening on stress-sensitive systems in the body. This fits the idea of Altenmüller and Schlaug (2012), who posited that music has both short-term and long-term effects on the brain, with the latter explaining how music can have enduring effects on health.

Furthermore, music listening has limitations in reducing stress. Results from paper II showed that when higher amounts of stress were experienced, music listening was not associated with a stress-reducing effect. At the same time, female patients with FMS did not benefit from music listening for stress reduction purposes, possibly due to already distorted stress systems. Therefore, depending on stress, mere music listening might not be sufficient to affect stress-sensitive systems in the body, and a more intense engagement with music (e.g., music making) might be necessary.

3.3. Implications

Three major implications regarding the framework in Figure 1.1 arise from the empirical evidence provided in papers I to VI, resulting in an update of the framework in Figure 3.2.

3.3.1. The complex interplay of characteristics of the music, the person, and the situation needs to be considered regarding their influence on the health-beneficial effects of music listening mediated by a reduction in psychobiological stress.

The empirical findings presented in papers II to VI suggest that the complex interplay among characteristics of the music, characteristics of the situation, and characteristics of the person is at work concerning the mechanisms underlying the stress-reducing effect of music listening. For example, paper II showed that the appraisal of the situation as stressful influences the stress-reducing effect of music listening. Thus, it might be likely that the appraisal of the situation interacts with characteristics of the music, e.g., when appraising a situation as stressful, different characteristics of the music might induce beneficial effects. Further, paper III showed that there are interactions among characteristics of the situation, with music listening for the reason of relaxation being associated with stress-reducing effects when solitary music listening is reported. Thus, depending on social characteristics, different music might be necessary for bringing about stress-reducing effects. In this regard, paper VI revealed that characteristics of the person interact with reasons for music listening as well as with the perceived arousal of the music in explaining stress-reducing effects. Based on the habitual experience of music-induced chills, different musical stimulation is necessary for benefitting from music for stress reduction purposes. In this manner, paper IV also provided hints that gender differences in the use of music shape experiences made with music in daily life.

Thus, in addition to Juslin et al. (2008), who suggested this distinction of characteristics of the music, the situation, and the person, the framework presented here cannot assume an independence of these three kinds of characteristics. Therefore, the framework in Figure 1.1 needs to be updated in terms of allowing interactions both among and within characteristics of the music, characteristics of the situation, and characteristics of the person (as illustrated by combining single notes into slurs in Figure 3.2).

3.3.2. Custom-tailored music interventions are necessary as different aspects of the music affect different stress-sensitive systems in the body.

The implications drawn from 3.3.1 need to be expanded by acknowledging individual differences concerning all elements of the model. People do not only differ in their music listening behavior; different health statuses and different set-ups of stress-sensitive systems in the body will also affect how music listening can exert health-beneficial effects. Thus, common to all ambulatory assessment studies is that music listening differentially affected HPA axis and ANS activity. In a health care setting, this knowledge should therefore be taken into account in terms of patients needing different music depending on their physiological stress reactivity. For example, patients suffering from chronic alterations in ANS activity might need different music than patients suffering from HPA axis dysfunctions.

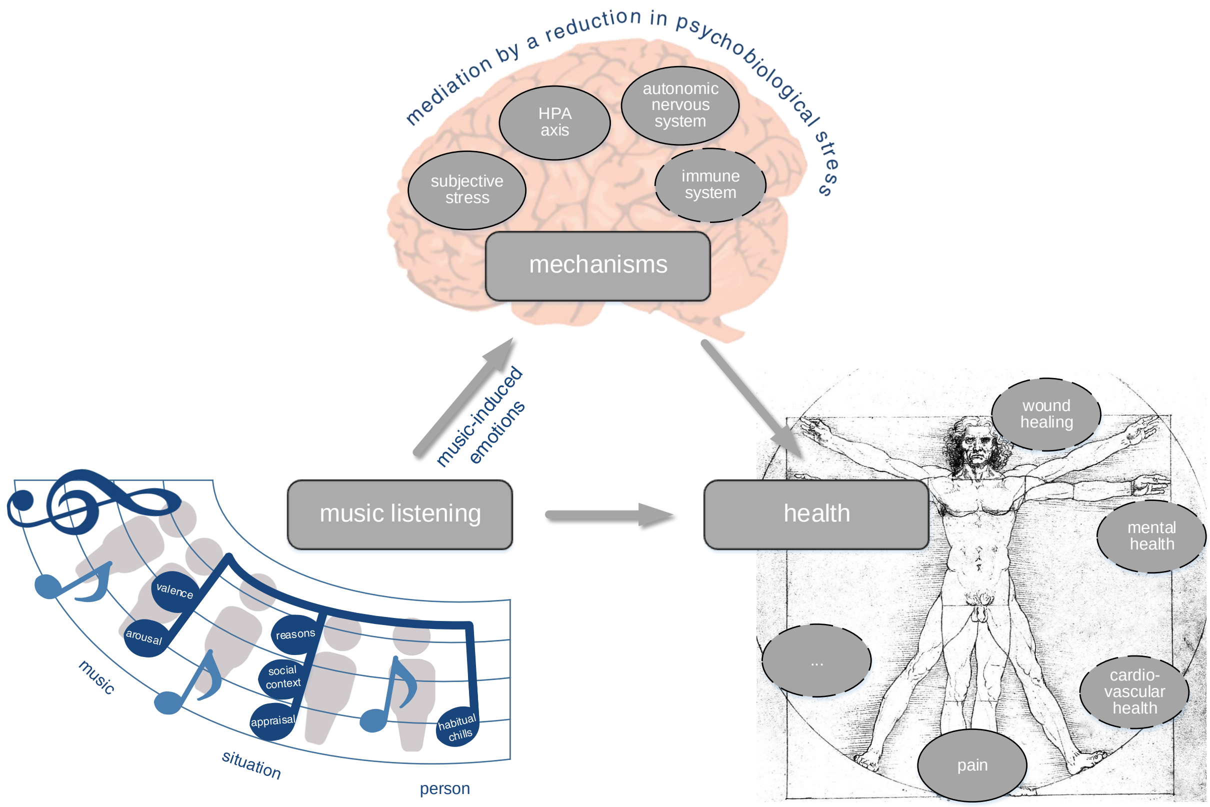
Consequently, the framework in Figure 1.2 needs to be updated by acknowledging the role of interindividual needs of music to affect stress-sensitive systems in the body (as reflected by the grey body shapes in Figure 3.2).

3.3.3. Music-induced emotions might multiply effects of music listening on stress-sensitive systems in the body.

As mentioned above, Koelsch (2014) posits that music-induced emotions are a prerequisite for modulating activity in limbic and paralimbic regions of the brain. Findings from the studies presented here support this notion. Different characteristics of the music affect different stress-sensitive systems in the body. In this regard, objective characteristics of the music affect ANS activity, whereas more complex analyses and evaluations of the music (e.g., with regard to social characteristics of the situation and reasons for music listening) were associated with HPA axis activity. Thus, early analysis of characteristics of the music was associated with ANS activity and later stages of musical analyses were associated with HPA axis activity. Characteristics of the situation therefore affect the limbic system at a later stage in music processing, which in turn affects the HPA axis through activity in the hippocampus and the amygdala. Accordingly, to affect these brain regions associated with the regulation of the HPA axis, music-induced emotions might be necessary or at least might intensify or multiply the effects which music listening has on stress-sensitive systems in the body. Indeed, this idea fits well with common stress theories, as Folkman (1997) expanded the transactional stress model by acknowledging the importance of both negative and positive emotions in the stress response. As stress research has so far predominantly focused on negative emotions, Folkman (2008) reviewed the importance of positive emotions on psychobiological stress. In this regard, positive emotions are thought to fulfill restorative functions. As music-induced emotions in daily life are often associated with positive emotions (Juslin et al., 2008), music listening might be one way to beneficially affect stress responses through music-induced emotions.

Consequently, the framework in Figure 1.2 needs to be updated with regard to an important role of music-induced emotions.

Figure 3.2: Adjusted framework for assessing health-beneficial effects of music listening mediated by a psychobiological reduction in stress



Annotations: HPA axis: hypothalamic-pituitary-adrenal axis; reasons: reasons for music listening (relaxation, distraction, activation, reducing boredom); appraisal: appraisal of a situation as stressful; habitual chills: habitual experience of music-induced chill; dashed lines refer to variables not assessed in this thesis

3.4. Limitations

Although the empirical evidence summarized in this thesis provides evidence of stress-reducing effects of music listening in daily life, certain limitations need to be discussed: First, together with momentary self-reports of stress, retrospective self-reports on music listening were gathered in all studies presented in papers II to VI. This means that potentially, up to four hours might have passed between music listening and the assessment of stress. Thus, these studies did not assess acute effects of music on stress-sensitive systems in the body, but rather intermediate effects. Accordingly, the concomitant assessment of salivary cortisol and salivary alpha-amylase does not allow the distinct reaction patterns of these two markers relative to stress to be accounted for. Nevertheless, as music listening has both short-term and long-term effects on the human body (Altenmüller & Schlaug, 2012), the findings here provide evidence for a modulation of these systems not only in an acute manner but also with intermediate effects that persist. Second, HPA axis and ANS activity were considered here as two stress-sensitive systems in the body. In this regard, it has to be acknowledged that, as mentioned above, the immune system interacts with these systems as well. In future studies, the effects of music listening in daily life on markers of the immune system need to be assessed in order to further understand mechanisms underlying the stress-reducing effect of music listening. Third, although this study is high in ecological validity, its internal validity could not be as rigorously controlled for as in experimental studies. As discussed by Smyth and Stone (2003), data quality is dependent on the compliance of the participants. In an attempt to assure compliance on multiple levels (with regard to the saliva collection procedure and with regard to compliance with the protocol in general), we tried to maximize internal validity. Furthermore, the high number of observations per person increases the power and allows a more naturalistic insight into the effects of music listening on stress (in comparison to experimental studies in which only one artificial music listening situation is examined).

3.5. Outlook

In order to further understand mechanisms underlying effects of music listening in daily life, event-based designs might be necessary. These allow acute effects of music listening on psychobiological stress to be investigated. Thus, a time-lagged assessment of salivary cortisol and salivary alpha-amylase relative to music listening enables acute effects of music listening to be captured. In a next step, a combination of experimental studies and ambulatory assessment studies would minimize limitations and maximize acquisition of scientific knowledge on mechanisms underlying the stress-reducing effect of music listening. By combining these two approaches, it should be possible to gather knowledge that is simultaneously high in both internal and external validity. This knowledge should be ultimately implemented in ecological momentary interventions targeting music listening behavior in daily life. Custom-tailored music interventions enable the identification of music that is optimal for specific groups (e.g., stressed individuals). Thus, this individualized approach allows music to be used in an efficient and goal-directed manner, as it can then meet the needs of specific population groups (e.g., patients, healthy participants at risk of certain diseases) in order for them to benefit from music listening.

3.6. Conclusion

Music listening in daily life is associated with stress-reducing effects depending on characteristics of the music, characteristics of the situation, and characteristics of the person. Mechanisms underlying this beneficial effect are closely linked to music's ability to modulate activity in the HPA axis and the ANS. Interestingly, music listening differentially affected these stress-sensitive systems in the body. It seems that different stages of music processing in the brain affect different stress-sensitive systems in the body. Thus, characteristics of the music were closely associated with ANS activity, whereas characteristics of the situation were associated with HPA axis activity. This gives rise to implications for the therapeutic use of music listening in daily life. Furthermore, individual differences in the habitual experience of music-induced chills account for interindividual differences in the stress-reducing effect of music listening.

Consequently, a complex interplay of characteristics of the music, characteristics of the situation, and characteristics of the person is at play when examining health-beneficial effects of music listening. A one-size-fits-all approach is therefore not favorable when implementing music for stress reduction purposes. Furthermore, a multi-dimensional approach assessing underlying mechanisms is warranted, as music listening differentially affects HPA axis and ANS activity.

To conclude, Oliver Sacks (1990) posits in his novel 'Awakenings' that 'the power of music to integrate and cure [. . .] is quite fundamental.' (p. 60). Further, he claims that music is 'the profoundest non-chemical medication.' (p. xiii). Thus, it is up to future research to better understand how music can be explicitly employed to achieve these 'fundamental' and 'profound' effects. Therefore, it is necessary to take into account the complex interplay among characteristics of the music, characteristics of the situation, and characteristics of the person in conjunction with the complexity of the human physiology. Then, it will be possible to ultimately employ music in the most efficient way as a means of stress reduction in daily life.

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Appendix A: Papers

Paper I

Linnemann, A., Strahler, J., & Nater, U.M. (in revision). Assessing the effects of music listening on psychobiological stress in daily life.

Journal of Visualized Experiments.

Please note: the authors have no conflict of interest.

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KEYWORDS: alpha-amylase, ambulatory assessment, ANS, cortisol, daily life, HPA axis, music listening, psychobiological stress, reasons for music listening, saliva

SHORT ABSTRACT: A study protocol is presented on how to assess associations between music listening and psychobiological stress (as measured by subjective stress levels, salivary cortisol, and salivary alpha-amylase) in daily life. Advice on study design, material and methods, selection of participants, and statistical handling is provided. Representative results are presented and discussed.

LONG ABSTRACT:
Music listening is associated with stress-reducing effects. However, most of the results on music listening and stress were gathered in experimental settings. As music listening is a popular activity of daily life, it is of utmost importance to study the effects of music listening on psychobiological stress in an everyday daily life setting. Here, a study protocol is presented that allows assessing associations between music listening and psychobiological stress in daily life by non-invasively

measuring salivary cortisol (as marker of the hypothalamic-pituitary-adrenal (HPA) axis) and salivary alpha-amylase (as marker of the autonomic nervous system (ANS)). The protocol includes advice on the study design (e.g., sampling pattern), material and methods (assessment of psychobiological stress in daily life, assessment of music listening, manual), selection of participants (IRB approval, inclusion criteria), and statistical analyses (multilevel approach). Representative results provide evidence for a stress-reducing effect of music listening in daily life. Interestingly, especially reasons for music listening (in particular relaxation) as well as the presence of others while listening to music increase this stress-reducing effect of music listening. At the same time, music listening in daily life differentially affects HPA axis and ANS functioning, thus emphasizing the need for a multi-dimensional assessment of stress in daily life.

INTRODUCTION:

Music listening is associated with stress-reducing effects[1,2]. However, most previous studies were conducted in experimental settings investigating highly selective patient populations. In particular, many studies were set in surgical settings in which music listening occurs either before, during, or after a stressful procedure[3]. Although these studies show beneficial effects of music listening, the findings remain equivocal. This might be due to a number of methodological reasons, i.e., different study methodologies and different study designs may lead to different results. For example, the artificial setting of a laboratory-based study makes it unclear whether findings from these experimental studies can be transferred to real-life environments. As music listening is a popular activity of daily life[4] that is often used for relaxation purposes[5-7], it is of utmost importance to study the effects of music listening on psychobiological stress (and its potentially underlying mechanisms) in everyday life settings that are characterized by high ecological validity.

Ambulatory assessment is defined as the simultaneous assessment of self-reports, behavior records, and/or physiological measurements in daily life while participants are going about their daily routine[8]. Ambulatory assessment studies are characterized by repeated measures of current experiences and behavior[9]. Therefore, it is possible to study dynamic relations among variables of interest with a minimum of recall bias and a maximum of ecological validity[10]. According to Shiffman, Stone and Hufford[10], studies set in daily life allow for (a) characterizing individual differences, (b) describing natural history, (c) assessing contextual associations, and (d) documenting temporal sequences. Furthermore, ambulatory assessment allows measuring stress in daily life from a psychobiological perspective, as self-reports and physiological markers can be assessed in the natural habitat of the participants. HPA axis and ANS activity can be non-invasively and concomitantly measured in saliva by means of salivary cortisol and salivary alpha-amylase, respectively[11].

Studies set in daily life encompassing both subjective as well as physiological markers are yet rare as most of the studies on music listening in daily life rely on subjective self-reports, e.g., [6,7,12-15]. From these studies, it can be concluded that music listening is a popular activity of daily life[13,15] that is associated with beneficial effects for subjective well-being[6,7,14]. Most interestingly, many studies find that music listening in daily life is associated with subjective feelings of relaxation[6,7]. Furthermore, relaxation is a common reason for music listening in daily life[6]. On the other hand, ambulatory assessment studies on the stress-reducing effect of music listening – particularly those encompassing both psychological as well as physiological indicators for stress – are very rare. We have previously shown in two ambulatory assessment studies that music listening is associated with a stress-reducing effect in healthy participants[16,17]. In contrast to these findings in healthy young adults, we were not able to find a stress-reducing effect of music listening in a patient sample[18].

Thus, it is of particular importance to study the effects of music listening in daily life using ambulatory assessment, as this approach allows examining a broad variety of situations in which music listening occurs with high temporal resolution (in comparison to an artificial situation in an experiment) and high external validity. Thus, by means of ambulatory assessment studies it is possible to investigate context factors influencing the effects of music listening in daily life. At the same time, underlying mechanisms can be investigated by means of concomitantly assessing physiological parameters. This approach renders it possible to unravel the complex mechanisms underlying the stress-reducing effect of music listening in daily life.

In this protocol, it is demonstrated how to assess the effects of music listening on psychobiological stress in daily life by elaborating on (1) study design (2) material and methods, (3) selection of participants, and (4) statistical considerations, based on the aforementioned studies[16-18]. This protocol follows the guidelines of the local ethics committee of the University of Marburg; for all reported studies[16-18] approval was obtained.

PROTOCOL:

1 Study Design: Sampling Pattern

1.1 Decide on the number of days, as most studies involving multiple assessments typically run from 3 days to 3 weeks[19]. Choose multiple consecutive days (e.g., at least seven days to encompass both weekdays and weekend days) in order to gain representative insights into the daily life of the participants.

1.2 Decide on number of assessments per day. Distribute assessments over the day, spanning representative periods between awakening and bedtime (e.g., six assessments per day).

1.3 Decide on distribution of assessments per day (e.g., assessments can either be event-based, time-based or a combination of these two designs[10]). Keep in mind that current recommendations prefer event-based procedures for sampling of rare events only, mostly for the reason of compliance and to keep up motivation of participants. Use a combination of event-based and time-based assessments:

1.3.1 Due to the diurnal rhythm of salivary cortisol and salivary alpha-amylase, use an event-based assessment directly after awakening.

1.3.2 Relative to this assessment, schedule one subsequent assessment 30 minutes after awakening and schedule further fixed assessments at 1200h (before lunch), 1400h, 1800h, and at 2100h (bedtime).

2 Material and methods

2.1 Electronic diary based data collection

2.1.1 Provide participants with a mobile electronic diary device on which they can answer the items occurring during the ambulatory assessment.

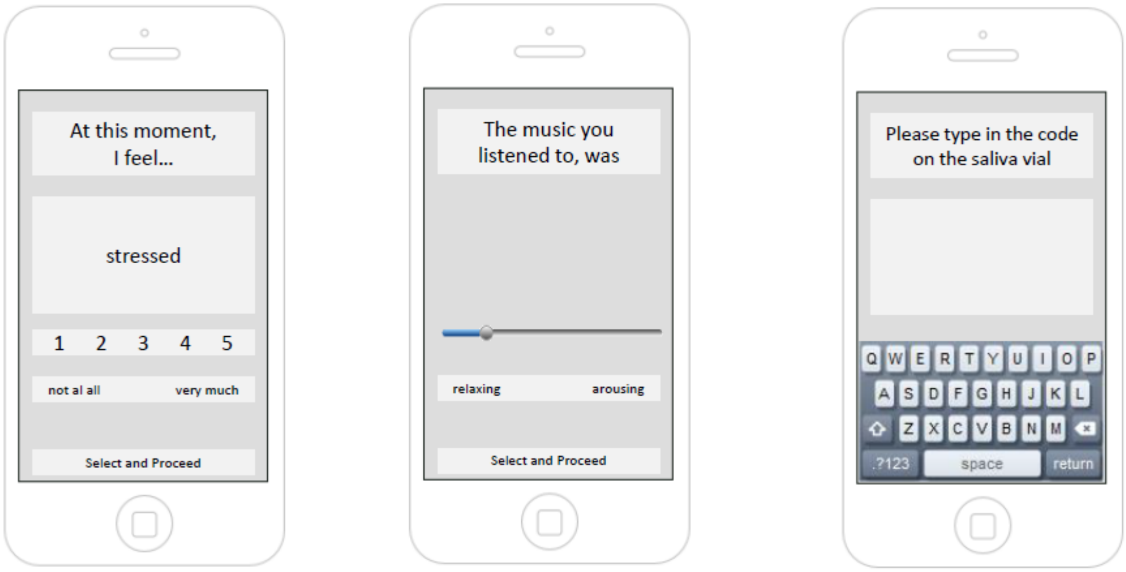

Figure 1: Exemplary screenshots from mobile diary devices.
Using electronic diary devices, participants can be investigated in their daily life while they are going about their daily routine.

2.2 Study manual

2.2.1 Prepare a manual in which the study material, the items occurring in the ambulatory assessment, as well as the procedure for the collection of saliva is explained in sufficient detail.

2.2.2 In this manual, describe each item in detail by explaining each response option.

2.3 Items on music listening

2.3.1 First, use a filter question to ask whether music listening has occurred since the last assessment.

2.3.2 Define what is meant by music listening by providing examples for music listening in daily life. Concentrate either on any music listening that occurs (e.g., background music while shopping) or on deliberate music listening (e.g., music listening that is in the focus of attention).

2.3.3 Ask subsequent items that cover a more in-depth characterization of the music listening episode when participants report having listened to music.

2.3.4 Ask for the perceived valence (ranging from sad to happy on a visual analogue scale) and perceived arousal (ranging from relaxing to energizing on a visual analogue scale) of the music that was listened to.

2.3.4.1 Give instructions on how to answer these items as follows: *Here, you are asked to define two qualitative characteristics of the music you listened to using different response scales: On the one hand, you are asked to rate whether you experienced the music as sad or happy. On the other hand, you are asked to rate whether you experienced the music as relaxing or energizing. It is about your subjective experience of the music. Please try to make a rating. If this is not possible, you may choose the middle of the scale. In case you listened to more than one piece of music, please make a rating representing the majority of music listened to. That is, if you listened to both sad and happy music on the radio, your classification should represent your predominant experience of the music.*

2.3.5 Assess reasons for music listening by asking the participants to choose the main reason for music listening (among relaxation, distraction, activation, and reducing boredom).

2.3.6 Give instructions on how to answer this item as follows by describing each response option:

2.3.6.1 *Music was listened to in order to relax. This can be due to some prior stressful event or to the general need to relax*.

2.3.6.2 *Music was listened to for activation. For example, you chose music to sing along or to move with or to activate yourself*.

2.3.6.3 *Music was listened to for distraction. That means, by means of music listening you tried to distract yourself from a certain topic or certain thoughts*.

2.3.6.4 *Music was listened to as there were no other alternatives available for reducing boredom. Contrarily to distraction as reason music listening, here music is not meant to distract from a certain topic or thoughts. Rather music is listened to to pass time.*

2.3.7 Assess characteristics of the listening situation.

2.3.7.1 Ask participants who were present when they were listening to music. In accordance to Juslin et al.[6], ask participants to choose among the following response options: ‘I was alone while listening to music’, ‘Friends were present while listening to music’, ‘Acquaintances were present while listening to music’.

2.3.7.2 Additionally, you may ask whether the participant was in the presence of strangers while listening to music[6].

2.3.7.3 Consult the appropriate literature on studies investigating music listening in daily life to learn more about these context variables[6,14].

2.4 Assessment of Psychobiological Stress

2.4.1 Stress is a multidimensional phenomenon that is assessed via subjective self-report as well as via physiological markers of stress.

2.4.2 Measure subjective stress using a single-item[20], that is how stressed they feel at the moment (e.g., on a five-point-Likert scale ranging from "not at all" to "very much").

2.4.3 At the same time as assessing subjective stress, ask your participants to collect saliva samples for the analysis of salivary cortisol and salivary alpha-amylase as neuroendocrine and autonomic stress markers, respectively.

2.5 Saliva Collection

2.5.1 For the concomitant assessment of salivary cortisol and alpha-amylase, use the passive drool method, which controls for the effects of mastication, textual stimulation, or interferences of absorbent material with assay procedures[21].

2.5.2 Pre-label your saliva vials as a fair amount of samples will be collected by using a simple unique code for each sample. This code consists of the study number + participant code + day of sampling + time of day.

2.5.3 Split samples according to day of sampling by placing all samples of one day into a small plastic bag.

2.5.4 Set a timer (e.g., 2 minutes are usually sufficient) on the mobile electronic diary device and ask participants to enter the code written on the vial as compliance check at the end of each assessment.

2.5.5 Weigh the saliva vials both before and after study participation to determine salivary flow rate (which is calculated by determining saliva volume (post to pre weight difference) divided by collection time (ml/min)).

2.5.6 Provide particular instructions for participants both face-to-face and as written instructions in the manual before the assessment period starts.

2.5.6.1 In order to avoid contamination with blood, sugar, or acidity, instruct your participants to not brush their teeth within 30 minutes prior sampling or have dental treatment 24 hours before sampling; major meals should not be consumed within 60 minutes prior to sampling; snacks and caffeinated or alcoholic beverages should not be consumed within 30 minutes prior to sampling, respectively.

2.5.6.2 Document intake of food and drinks as well as nicotine by means of mobile electronic diary device by asking “Did you eat/drink/smoke within the last two hours?” (0 “no”, 1”yes”).

2.5.6.3 Ideally, ask your participants to rinse their mouth with tab water 10 minutes prior to sampling. Afterwards, each sampling is performed as described above.

2.5.6.4 Ask your participants to document vigorous physical activity two hours prior to sampling (“Have you been active, and if yes, how active have you been during the last 2 hours” – “not at all” – “very little” – “moderately” – “vigorously”).

2.5.7 Ask your participants to store samples at or below -20°C as soon as possible (on the evening of each day at the latest) to prevent bacterial growth.

2.6 Covariates

2.6.1 Due to the assessment of biological parameters, control for body mass index (BMI) and gender. Either define inclusion criteria regarding BMI and gender (e.g., include only those subjects who have a BMI equal or lower than 30, or include only men or women), or statistically control for the influence of BMI and gender.

2.6.2 Concerning the association between music listening and stress, control for musical expertise and music preference, e.g. by means of the Music Preference Questionnaire (MPQ-R)[22], in order to test hypotheses on differential effects concerning the associated between music listening and stress based on personal music preference and expertise.

2.6.3 Ask participants to complete the Trier Inventory for Chronic Stress[23] and/or the Perceived Stress Scale[24] to test hypotheses regarding the influence of overall stress levels during the last weeks on the association between music listening and current stress.

3. Selection of participants

3.1 Obtain IRB approval with special attention to potential intrusiveness of study participation on daily life routines and with special attention to the collection of salivary biomarkers for stress.
3.2 Perform an a priori power analysis as recommended by Bolger, Stadler and Laurenceau[25] if you have a priori knowledge on expected effect sizes.

3.3 Cautiously select study participants and define the following inclusion criteria:

3.3.1 Participant’s age range should be as narrow as possible (or considered to be a confounder and treated as such statistically), e.g., 18 to 35 years of age.

3.3.2 BMI < 30

3.3.3 Either being a non-smoker or smoking less than five cigarettes per week

3.3.4 No consumption of drugs (no consumption of cannabis within the last two weeks, no consumption of any other psychotropic substances within the last four weeks)

3.3.5 No intake of any medication (except for hormonal contraceptives (HC) in females, but use of HC should be recorded and considered within statistical analyses)

3.3.6 No chronic somatic or psychiatric disease (according to self-reports based on the Patient Health Questionnaire (PHQ) [26]).

4. Meeting with Participants

4.1 Schedule an introductory session with the participants to accommodate them with the mobile device, questionnaires, and saliva collection method.

4.2 Familiarize all participants with how to handle the electronic diary.

4.3 Provide each participant with information on how the mobile electronic diary device is used (e.g., how to turn it on and off, how to mute the alarm and unmute it, how to react when missing an assessment, frequency of recharging).

4.4 Explain and demonstrate all functions concerning the study.

4.5 Make sure to do a trial run with your participant and review the manual with the participant.

4.6 Collect a saliva sample for demonstration purposes.

4.7 Provide the participant with contact details in case of technical problems.

4.8 Set a date for the post-monitoring session.

4.9 Tell your participant to start the first assessment the day following the introductory session.

4.10 After completion of data collection, ask participants to return to the laboratory to hand over the study equipment (iPod touch, saliva samples).

4.11 After completion of data collection, conduct a standardized post-monitoring interview asking for any problems that may have occurred during the study, interference of study participation with daily life routine, and overall satisfaction with the study participation.

5. Statistical Handling

5.1 Due to the nested structure of the data (here: repeatedly assessed music listening and psychobiological stress is nested in persons), perform hierarchical linear modeling.

5.2 Prepare your data set by excluding participants with less than 50% of completed assessments.

5.3 Check your data for normal distribution. As salivary cortisol and salivary alpha-amylase are usually not normally distributed, transform your data, e.g. using the formula ln (x) + 10.

5.4 Analyze your data using HLM[27] in accordance with the procedure described by Woltman, Feldstain, MacKay and Rocchi[28]. Analyses should at least control for time of day on level-1 and for BMI and gender on level-2.

5.5 Calculate the amount of explained variance as indicator for effect size using the formula provided by Singer and Willet[29].

REPRESENTATIVE RESULTS:
This protocol is meant to provide one example on how the effects of music listening on psychobiological stress in daily life can be examined. The procedures are designed to investigate associations between music listening, subjective stress reports, concentration of salivary cortisol, and activity of salivary alpha-amylase.

Representative results presented in the following are examples from three publications from our work group published in Psychoneuroendocrinology[16,17] and Frontiers in Human Neuroscience[18]. Please refer to these papers for a more detailed description of both theoretical background and results. In study 1[16], a total of 55 healthy participants was examined for a total of ten days. A sub-sample of 25 participants provided saliva samples on four days. In study 2[17], a total of 53 healthy participants provided a saliva sample after each assessment for the duration of seven consecutive days. In study 3, a total of 30 female patients with fibromyalgia syndrome was examined for fourteen consecutive days[18].

Music listening and psychobiological stress
In study 1, deliberate music listening was associated with lower subjective stress levels. However, no effects on psychobiological markers of stress were found (see Table 1). In study 2 and 3, no effects of mere music listening on psychobiological stress were found[17,18].

Table 1: Hierarchical linear models predicting repeatedly assessed momentary stress salivary cortisol secretion, and salivary alpha-amylase activity using restricted maximum likelihood (reprint with permission from Linnemann et al.[16])

	Model 1a: changes in subjective Stress by music episode		Model 1b: changes in sCort by number of music episode		Model 1c: changes in sAA by number of music episode	
Fixed Effects	Unstandardized Coefficients	SE (df), *p*	Unstandardized Coefficients	SE (df), *p*	Unstandardized Coefficients	SE (df), *p*
Intercept Level-2	1.17	0.12 (48), ≤ *0.001*	11.95	0.13 (22), ≤ *0.001*	10.55	1.18 (22), ≤ *0.001*
Gender	0.20	0.14 (48), *0.153*	0.34	0.13 (22), *0.012*	-0.04	0.28 (22), 0.875
BMI[1]			-0.02	0.02 (22), *0.425*	0.16	0.16 (22), 0.011
Music Episode (0/1)[2]	-0.17	0.06 (49), *0.010*	-0.01	0.01 (24), *0.915*	0.04	0.09 (24), 0.678
Time of Day[3]			-0.45	0.04 (24), ≤ *0.001*		
Random Effects	Variance Component	SD (df), *p*	Variance Component	SD (df), *p*	Variance Component	SD (df), *p*
Intercept Level-1	0.25	0.50 (47), ≤ *0.001*	0.05	0.23 (19), *0.012*	0.63	0.80 (19), ≤ *0.001*
Music Episode slope	0.06	0.25 (48), *0.029*	0.02	0.13 (21), *>0.500*	0.00	0.06 (21), 0.447
Residual	0.86	0.93	0.36	0.60	0.55	0.74

Note. [1] BMI was only entered in analyses predicting sCort and sAA, [2] (0/1): 0 = no music episode, 1 = music episode, [3] Time of day was only entered in analyses predicting sCort

Perceived valence and arousal of music and stress

The perceived arousal of the music was associated with salivary alpha-amylase activity in study 1 and 2[16,17]. In study 1, music which was rated as low in arousal predicted reduced salivary alpha-amylase activity ($UC = 0.01$, $t(110) = 2.272$, $p = 0.025$) with arousal explaining 3.55% of the variance in salivary alpha-amylase[16]. In study 2, the same pattern of results emerged with music low in arousal reducing salivary alpha-amylase activity[17]. In all studies, no effect of perceived valence on psychobiological stress, were found[16-18].

Reasons for music listening and stress

In study 1 and 2, only music that was listened to for the reason 'relaxation' yielded lower subjective stress ratings. In study 1, the reason 'relaxation' explained 6.50% of the variance in stress levels[16]. Concerning salivary cortisol concentrations, it was shown that in accordance with the results on self-reported stress, music that was listened to for the reason 'relaxation' yielded lower salivary cortisol concentrations ($UC = -0.48$, $t(113) = -3.513$, $p \leq 0.001$) explaining 12.44% of the variance in salivary cortisol[16]. In study 2, music that was listened to for the reason of relaxation was associated with lower subjective stress levels[17]. In study 3, only music that was listened to for the reason of activation was associated with lower subjective stress explaining 2.42% of variance in subjective stress[18].

Presence of others while listening to music and stress

In study 2 the social context of the listening situation was assessed. It was shown that listening to music in the presence of others was associated with lower subjective stress reports, lower salivary cortisol secretion, and higher salivary alpha-amylase activity. Most interestingly, the effect of music listening in the presence of others exceeded the effect of mere music listening and of the presence of others when the assessment was triggered (Figure 2).

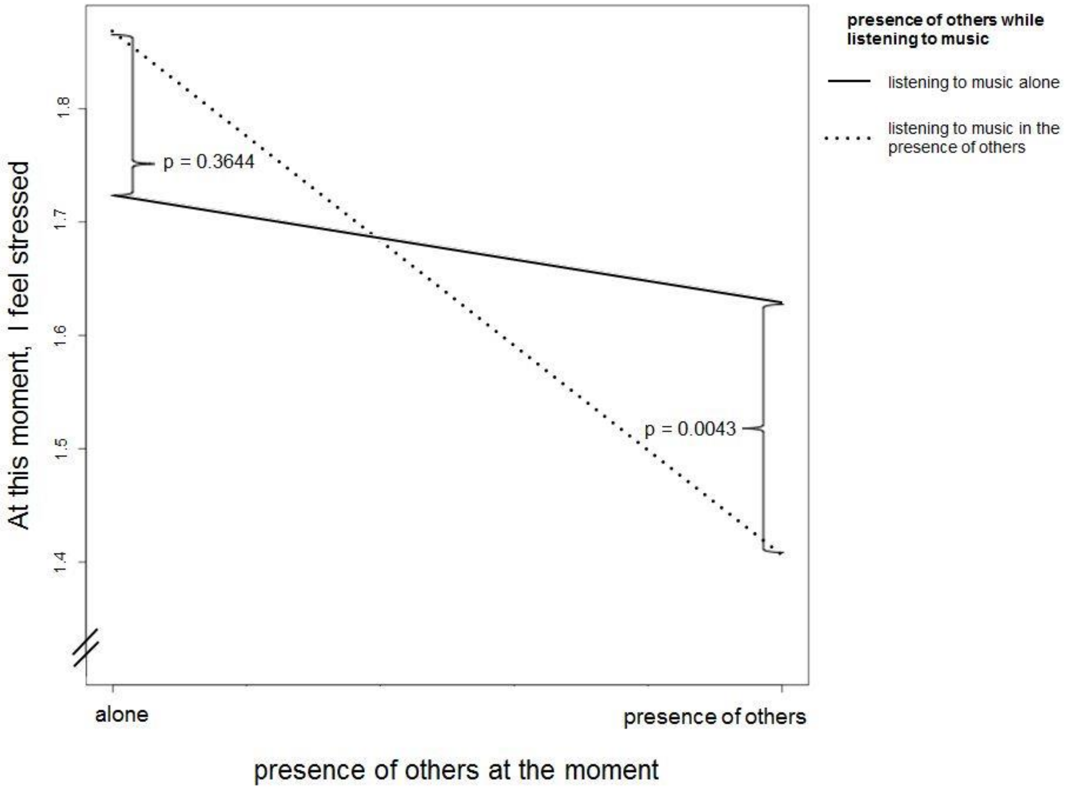

Figure 2: **Mean subjective stress level and presence of others while listening to music (modified from Linnemann, Strahler, and Nater[17]).**
Subjective stress was lowest, when participants listenined to music in the presence of others. Furthermore, there was a significant interaction of presence of others while listening to music and presence of others when the assessment was triggered. Thus, subjective stress was lowest, when music was listened to in the presence of others and others were present when the assessment was triggered.

DISCUSSION:
Here a study protocol is presented on how to investigate the effects of music listening on psychobiological stress in daily life. The advantage of the ambulatory assessment design is that the effects of music listening on stress can be investigated in the natural habitat of the participants while they are going about their daily routine.
As this study protocol assesses past music listening and momentary stress, short-term effects of music listening on stress can be examined. In line with experimental studies, a stress-reducing effect of music listening depending on characteristics of the music and depending on characteristics of the situation was found. In this regard, ambulatory assessment studies allow further characterizing this association. As music listening in many different situations is captured, the role of characteristics of the music (e.g., valence and arousal) as well as characteristics of the situation (e.g., reasons for music listening, presence of others while listening to music) can be explored across various different situations.
Critical steps within this protocol
The descriptions provided in the manual are critical to the data quality. For example, if it is not

properly defined what is meant by music listening by providing examples for music listening in daily life, participants might define music listening episodes differently. Therefore, it needs to be described whether participants are asked to report any music listening that occurs or whether participants are asked to focus on deliberate music listening only.
Concerning the collection of saliva samples in daily life, this might be experienced as unpleasant by some participants in the early beginning of the study. However, these feelings vanish almost immediately. Pre-labelling and preparation of samples is essential in order to reduce participant burden and increase compliance with the protocol. Furthermore, oral and written instructions on how to provide a saliva sample is of utmost importance. In this regard, participants should be equipped with a written manual containing the above mentioned precautions and instructions.

Modifications of the design
The advantage of the items on music listening as they are described in this protocol is that they allow studying the temporal dynamics of the effects of past music listening on current stress. However, this design might be modified in case acute effects of music listening on stress are of interest. Then both momentary music listening and momentary stress should be assessed in order to examine simultaneous effects. There are studies in which both simultaneous and past music listening are assessed e.g.,[13,14]. Furthermore, in order to prevent relying solely on subjective self-reports on music listening, the design can be modified by objectively assessing music listening. In this regard, Juslin et al.[6] discuss the use of the electronically activated recorder[30] to objectively assess the sound environment of participants. Furthermore, music streaming platforms might be used to track the exact music titles participants are listening to.

Limitations of the technique
However, cautious interpretation of the findings gathered when using this study is warranted: First of all, conclusions regarding causality are restricted. As no random assignment to experimental conditions takes place, study results should be interpreted as associations. Nevertheless, this does not affect the quality of results as the number of observations is high in ambulatory assessment studies. Thus, it is quite unlikely that associations are driven by extraneous variables. Furthermore, controlling for variables associated with salivary cortisol and salivary alpha-amylase (such as smoking, drinking, eating, and physical activity) further increase the reliability and validity of the results[31,32].
Second, the concomitant assessment of salivary cortisol and salivary alpha-amylase deserves special attention as well. Salivary cortisol and salivary alpha-amylase underlie different diurnal rhythms[11] and show distinct temporal dynamics in reaction to a stressor[33]. Therefore, event-based methods might be warranted when acute effects of music listening on psychobiological are of interest. Then, time-lagged collection of salivary alpha-amylase and salivary cortisol relative to music listening is necessary in order to account for the distinct temporal dynamics of salivary alpha-amylase and salivary cortisol.
Third, it has to be critically kept in mind that subjective stress is assessed using a single-item approach, as the number of items has to be cautiously balanced against burden for participants. Therefore, a more comprehensive assessment of stress might improve validity.

Significance of the technique with respect to existing methods
Although there are (though very few) studies assessing the effects of music listening on stress in daily life, they solely rely on self-reports. Until now, physiological effects of music listening were

predominantly examined in experimental studies. Laboratory studies allow for controlling for a wide range of potential confounders and, at the same time, facilitate assessment of biological stress markers using invasive equipment (such as needles for blood collection). However, with the advancement of salivary stress markers, the assessment of psychobiological stress is not limited to the constraint of the laboratory anymore. Thus, the significance of this approach is that it provides methodological considerations on how to design studies in daily life that allow investigating the effects of music listening on stress beyond the scope of subjective stress ratings.

Future applications after mastering this technique

Assessing the effects of music listening on psychobiological stress in daily life will allow for important insights into mechanisms underlying the health-beneficial effect of music listening. With music listening being a popular, cost-effective, and easily applicable activity of daily life, interventions can be developed that specifically target music listening behavior in daily life. By means of ecological momentary interventions, specific population (e.g., highly stressed individuals) can be reminded to listen to music for the reason of relaxation for stress reduction purposes. Furthermore, as smartphones allow assessing physiological stress markers, participants might receive immediate biofeedback on how music listening affected their physiological stress level. Thus, this protocol helps investigating the potential of music listening as a means of stress reduction in daily life. Knowledge gathered based on this protocol will be of great importance for the design of music interventions in daily life.

Conclusion

Taken together, a study protocol for assessing the effects of music listening on psychobiological stress in daily life is presented. Studies set in daily life offer important avenues for research and at the same time they bear challenges. The high ecological validity and high temporal resolution of processes that can be captured in daily life are two important advantages of ambulatory assessment studies. Beyond the scope of the constraints of experimental environments, research results with high ecological value can be gathered as they allow translating research findings into daily life. At the same time, internal validity cannot be as high as in experimental studies. Therefore, a diligent recruitment, diligent preparation of study material, and cautious interpretation of results is necessary.

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Paper II

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Music listening as a means of stress reduction in daily life

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Music listening;
Stress reduction

Summary The relation between music listening and stress is inconsistently reported across studies, with the major part of studies being set in experimental settings. Furthermore, the psychobiological mechanisms for a potential stress-reducing effect remain unclear. We examined the potential stress-reducing effect of music listening in everyday life using both subjective and objective indicators of stress. Fifty-five healthy university students were examined in an ambulatory assessment study, both during a regular term week (five days) and during an examination week (five days). Participants rated their current music-listening behavior and perceived stress levels four times per day, and a sub-sample ($n = 25$) additionally provided saliva samples for the later analysis of cortisol and alpha-amylase on two consecutive days during both weeks. Results revealed that mere music listening was effective in reducing subjective stress levels ($p = 0.010$). The most profound effects were found when 'relaxation' was stated as the reason for music listening, with subsequent decreases in subjective stress levels ($p \leq 0.001$) and lower cortisol concentrations ($p \leq 0.001$). Alpha-amylase varied as a function of the arousal of the selected music, with energizing music increasing and relaxing music decreasing alpha-amylase activity ($p = 0.025$). These findings suggest that music listening can be considered a means of stress reduction in daily life, especially if it is listened to for the reason of relaxation. Furthermore, these results shed light on the physiological mechanisms underlying the stress-reducing effect of music, with music listening differentially affecting the physiological stress systems.

1. Introduction

Stress has the potential to be a major health threat facilitating the development of disease and illness (McEwen, 1998). As stress is a ubiquitous phenomenon in everyday life, it is necessary to develop interventions that can target stress in daily life and thus prevent its detrimental effects

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on health. It is assumed that music listening has health-beneficial effects, which might be mediated by its potential stress-reducing effect (Thoma and Nater, 2011). However, the empirical evidence on the stress-reducing effect of listening to music is far from being consistent, and the underlying psychobiological mechanisms of this potential stress-reducing effect — especially in daily life — remain unknown.

1.1. Music listening as a means of stress reduction in daily life

While the effects of music therapy (for an overview see Hanser, 2010) and music making (e.g., Bittman et al., 2013) on health-related outcomes have been studied in a plethora of (experimental) studies, the effects of mere music listening remain understudied. Particularly due to the fact that music is present in everyday life (Hargreaves and North, 1999; Juslin and Laukka, 2004; Krause et al., 2015), it is an important endeavor to study the effects of music listening in ecologically valid settings (Skanland, 2013). Results from research in experimental settings and in clinical contexts suggest that music listening has the potential to reduce stress, both subjectively and physiologically. For example, Sandstrom and Russo (2010) found that music high in valence and low in arousal positively affected recovery of heart rate and skin conductance levels after a stressor. Although most studies support the notion that music low in arousal is stress-reducing, Chanda and Levitin (2013) suggest that context factors, such as control over music selection (experimenter- vs. participant-selected), need to be considered as well. In contrast to experimental studies in which the context of listening to music is highly artificial, recent research efforts suggest that it might be more ecologically valid to study music in people's natural habitat (North et al., 2004; van Goethem and Sloboda, 2011).

Only a small number of studies have investigated music listening in daily life (Greasley and Lamont, 2011; Juslin et al., 2008; Krause et al., 2015; Randall et al., 2014; Skanland, 2013; van Goethem and Sloboda, 2011). These studies predominantly describe music-listening behavior, and to date, no study has directly investigated the effects of music listening on both subjective and physiological stress. Some studies do hint at the idea of a stress-reducing effect of music listening in daily life (Juslin et al., 2008; van Goethem and Sloboda, 2011). Juslin et al. (2008), for example showed that listening to music increased feelings of calmness. Still, research investigating this potential stress-reducing effect from a multi-dimensional perspective, exploring both subjective and physiological measures of stress, and considering both musical and nonmusical context factors in this relationship, is lacking.

1.2. Beyond self-reports: The effect of music listening on the physiological stress response

Music listening has been associated with a down-regulation of the hypothalamic—pituitary—adrenal (HPA) axis, as shown via reductions in the concentrations of cortisol in various experimental and clinical contexts (for an overview see: Kreutz et al., 2012), as well as with alterations of autonomic nervous system activity, with decreases in heart rate and blood pressure (for an overview see: Hodges, 2011). However, the pattern of results concerning biological effects of music is not consistent. Some studies failed to find an effect of music on stress-related physiological changes. Chlan et al. (2013), for example, found no effect of music listening on cortisol levels in mechanically ventilated patients. However, another study found a beneficial effect of music listening on parameters of the autonomic nervous systems in mechanically ventilated patients (Han et al., 2010). A plethora of studies (either investigating patients or healthy participants) report discrepant findings when comparing self-reports of stress to physiological markers of stress (DeMarco et al., 2011; Gerra et al., 1998; Thoma et al., 2013): for example, Thoma et al. (2013) found relaxing music to be less effective in reducing cortisol concentrations than the sound of rippling water, whereas there was no difference with regard to subjective stress levels. The same pattern emerged in the study by DeMarco et al. (2011) in which music reduced subjective stress levels but not heart rate and blood pressure in patients undergoing surgery. This heterogeneity of findings is probably due to methodological issues, such as different music selection and/or varying intensity of stressors, thus emphasizing the need to further study the effect of context variables on the stress-reducing effect of music listening.

1.3. The need to consider context variables: Valence/arousal, reasons for music listening, and stress intensity

To date, there is no empirically sound knowledge on which music (in terms of valence and arousal) is particularly effective for stress reduction purposes (Sandstrom and Russo, 2010). To the best of our knowledge, only one experimental study has systematically investigated the effect of the valence and arousal of music in the context of stress. In this aforementioned study, Sandstrom and Russo (2010) were able to show that recovery from a stressor worked best if participants listened to music which was low in arousal and positive in valence. However, in daily life, no study so far has related valence and arousal ratings to the stress-reducing effect of music listening

Juslin et al. (2008) suggest that the emotional effect of music varies as a function of reasons for music listening. Since 'relaxation' is one of the main reasons why individuals listen to music (Greasley and Lamont, 2011; Juslin et al., 2008; van Goethem and Sloboda, 2011), it seems plausible to examine reasons for music listening in the context of the stress-reducing effect of music listening. To date, no study has empirically examined whether reasons for music listening may affect the stress-reducing effect of music listening in daily life.

In her review on the stress-reducing effect of music listening, Pelletier (2004) summarized that music may only be effective in reducing stress in the context of a mild stressor as opposed to a strong stressor. This finding was corroborated by a recent experimental study from our group (Thoma et al., 2013), which found that listening to music prior to a (strong) socio-evaluative stressor was not effective in reducing stress, thus emphasizing the idea that the stress-reducing effect of music may vary as a function of stressor intensity. However, so far, no study has examined the effect of real-life stressors of varying intensity on the stress-reducing effect of music listening in daily life.

1.4. Research question

Current evidence on music listening and stress is inconclusive. Many studies are set in experimental settings, thus limiting the generalizability of the results to daily life. However, as stress is a ubiquitous phenomenon and music listening is an activity of daily life, it seems of utmost importance to study the relationship between music listening and stress in an ecologically valid setting. As it remains unanswered which psychobiological mechanisms underlie the stress-reducing effect of music listening, it is necessary to combine subjective stress levels with physiological markers of stress to better understand under which circumstances what kind of music is effective in reducing stress.

Based on the available research findings, we hypothesized that music listening in daily life is associated with a subsequent reduction in stress, both subjectively and physiologically (Model 1). Furthermore, we were interested in whether context factors such as perceived valence and arousal of the selected music (Model 2), reasons for music listening (Model 3) and stress intensity (Model 4) influence the stress-reducing effect of music listening in daily life.

2. Method

2.1. Participants

A convenience sample with a total of 55 healthy students (35 female, 20 male) participated in the study. As females are over-represented in German Psychology classes, the proportion of females is higher as males in this study. Participants' ages ranged from 18 to 31 years with a mean of $M = 23.20$ ($SD = 3.11$) years. Four participants dropped out of the study after having completed the first measurement condition (due to technical problems or non-compliance). Recruitment was carried out by means of emails sent to university mailing lists. The eligibility criteria were as follows: German as native language, 18—35 years of age, BMI <30, fewer than five cigarettes per week, no current drug consumption, no intake of medication (except hormonal contraceptives), no chronic somatic or psychiatric disease, regular menstruation, no pregnancy, no breast-feeding. Participation in the study was voluntary and each participant received either 50 Euro or course credit as compensation. The study was approved by the local Ethics Committee of the Department of Psychology at the University of Marburg, Germany.

2.2. Procedure

The study used a within-subject design, in which participants were examined twice: at the beginning of a semester (henceforth referred to as control condition) and at the end of a semester, when exams are typically being taken in the German university system (henceforth referred to as exam condition) for five consecutive days each. During an introductory session, participants were familiarized with the handling of a pre-programmed iPod® touch (iDialogPad), on which they were required to complete six assessments on each day. The first assessment had to be triggered by the participant directly after awakening. Subsequently, a timer activated the next assessment after 30 min. Following this, assessments ensued at four time points: at 1000 h, 1400 h, 1800 h, and 2100 h. In case participants missed an assessment, they were reminded for up to four times every 5 min. The compliance rate was high in this study, with a relatively small number of missing data. The number of missing data was 1000 h assessment: $n = 159$ (i.e. 7.23% of all data points), 1400 h assessment: $n = 39$ (i.e. 1.77% of all data points), 1800 h assessment: $n = 37$ (i.e. 1.68% of all data points), 2100 h assessment: $n = 41$ (i.e. 1.86% of all data points).

A subsample ($n = 25$, 18 women) was asked to collect a saliva sample after each assessment on two consecutive days during both measurement conditions.

2.3. Measures

For the purpose of analyzing relationships between music listening and stress, only the assessments at 1000 h, 1400 h, 1800 h, 2100 h will be considered here, as only these assessments contained items on both stress and music-listening behavior.

2.3.1. Stress

Stress was assessed using a multi-dimensional approach: By means of real-time data collection, both subjective and physiological stress was measured.

Momentary subjective stress: Momentary subjective stress levels were measured using the item 'At this moment, I feel stressed', which was answered on a 5-point Likert scale ranging from 0 to 4. Low scores indicate low levels of stress and high scores indicate high levels of stress, respectively. In order to keep the compliance rate as high as possible we decided to use a single-item measure for stress which has recently been shown to have sufficient psychometric properties (Elo et al., 2003).

Physiological stress markers: Salivary cortisol (sCort) and salivary alpha-amylase (sAA) were measured. Cortisol is a hormone representing the activity of the hypothalamic—pituitary—adrenal (HPA) axis and is a valid biomarker of stress (Hellhammer et al., 2009). Alpha-amylase is an enzyme in saliva which can be considered as a biomarker for stress-related changes in the activity of the autonomous nervous system (ANS) (Nater and Rohleder, 2009). Both sCort and sAA can be concurrently measured non-invasively in daily life settings (e.g., Nater et al., 2013; Rohleder et al., 2008). In order to collect data on sCort and sAA, participants were asked to collect whole saliva using the SaliCap® system (IBL, Hamburg, Germany) by not swallowing for 2 min and then transferring all accumulated saliva into a pre-labeled vial via a straw. In order to control for participants' compliance, they were asked during each daily assessment on the iPod® to enter the number printed on the tube they were using. Participants were asked to store the tubes as cool as possible in their freezers or fridges at home. At the end of each assessment period, the tubes were stored at $-20\,^{\circ}$C in freezers at the Biochemical Laboratory of the Department of Psychology, University of Marburg, until analysis. sCort levels were measured using a commercially available enzyme-linked immunoassay (IBL, Hamburg, Germany). sAA activity was measured using a kinetic colorimetric test and reagents obtained from Roche (Fa. Roche Diagnostics, Mannheim, Germany). Interassay variance was 10.9% for sAA and 6.5% for sCort, and intraassay variance was 6.5% for sAA and 6.2% for sCort.

2.3.2. Stress intensity

Furthermore, to assess the impact of stress intensity on the potential stress-reducing effect of music listening, participants completed the assessments during two conditions of varying stress intensity. Therefore, we chose to examine the stress-reducing effect once during a (less stressful) control condition at the beginning of a semester and once during a (more stressful) exam condition at the end of a semester. This decision was based on the evidence that academic examinations are a major contributor to students' stress levels (Abouserie, 1994).

2.3.3. Music-listening behavior

Ambulatory assessment: The first item on participants' music-listening behavior addressed the question of whether participants had been deliberately listening to music since the last assessment. Deliberate music listening was defined as 'actively selecting music and consciously listening to it'. For example, background music while shopping was not considered as deliberate music listening, whereas music listening via electronic devices was considered as deliberate music listening. Based on this item, the daily assessments were classified as 'non-music episodes' if no deliberate music listening was reported and 'music episodes' if deliberate music listening was reported. More music-related questions followed only if participants confirmed that they had deliberately listened to music. Participants were asked to evaluate the music on a visual analogue scale (0 to 100). The wording of the question was as follows: 'The music you have been listening to, was ...'. Participants indicated the perceived valence (ranging from 0 (sad) to 100 (happy)) and arousal (ranging from 0 (relaxing) to 100 (energizing)) of the music they had been listening to. Afterwards, they were asked to indicate reasons for listening to music. In accordance with the existing literature, we selected those reasons which have been most frequently reported in recent studies on music listening in daily life (Juslin et al., 2008; Linnemann et al., 2015; van Goethem and Sloboda, 2011): 'relaxation', 'activation', 'distraction', and 'reducing boredom'. For each reason, participants indicated whether it applied or not. Thus, multiple responses were possible.

Questionnaire: The Music Preference Questionnaire (MPQ) (Nater et al., 2005) was used to gain insight into participants' habitual music preference and situations in which they usually decide to listen to music. It comprises items measuring participants' music preference, their reasons for listening to music, and the average time they spend listening to music. Furthermore, on a scale ranging from 1 (not important) to 5 (very important), participants indicated the significance of music in their lives. This questionnaire was available online and participants were asked to fill it out during the first measurement period.

2.4. Data analysis

In order to account for the nested structure in the data, analyses are based on hierarchical linear modeling (HLM) (Raudenbush et al., 2004). Subjective stress, sCort, sAA, and items on music listening (music episode (yes/no), perceived valence, perceived arousal, reasons for music listening) were considered level-1 variables. In analyses concerning the relationship between music episode and sCort, time of day has been added as predictor ($UC = -0.45$, $t(363) = -16.57$, $p \leq 0.001$). However, in analyses concerning valence/arousal and reasons for music we refrained from adding time of day as predictor for two reasons: First, the number of level-1 observations is already relatively small, as only music episodes could enter analyses. Therefore we aimed at models which were parsimonious in order to avoid type-B error inflation. Second, as music listening was most often reported in the late afternoon and evening (both in the data set in which all observations were included ($UC = 0.03$, $t(2119) = 2.914$, $p = 0.004$) as well as in the data set in which only the observations were included from participants who provided saliva samples ($UC = 0.05$, $t(361) = 2.151$, $p = 0.032$)), we assume that the role of diurnal variations in sCort was kept to a minimum in these analyses. At the individual level (level-2), the intercept (β_0) was modeled as a function of gender (γ_{01}) and a residual component (u_0). In analyses concerning physiological parameters, body mass index (BMI) was entered at the individual level (level-2) due to its known association with HPA axis regulation.

Using HLM, both unconditional and conditional models were specified in accordance to the procedure described by Woltman et al. (2012). The comparison between these models was undertaken by means of χ^2-statistics, comparing the reduction in deviance as a measure of model fit. p-Values of ≤ 0.05 were considered significant. For all analyses, unstandardized coefficients (UC) are presented.

The subsample ($n = 25$, 18 female) that additionally provided saliva samples did not differ from the total sample either regarding music-listening behavior (number of music episodes: $M = 0.30$ vs. $M = 0.27$; $t(2090) = 1.51$, $p = 0.131$) or regarding stress levels ($M = 1.27$ vs. $M = 1.19$; $t(2090) = 1.72$, $p = 0.086$). Biological data were checked for normality using the Kolmogorov–Smirnov test. Both sCort and sAA were log-transformed due to non-normality using the formula $\ln(x) + 10$. In all tested models concerning sCort, women showed higher sCort concentrations than men ($UC \geq 0.29$, $t(22) \geq 2.19$, $p \leq 0.039$). BMI did not account for variation in sCort ($UC \geq -0.03$, $t(22) \leq -0.83$, $p \geq 0.413$). With regard to sAA, the reverse pattern emerged: Gender was not associated with sAA ($UC \geq -0.26$, $t(22) \leq -0.54$, $p \geq 0.595$), whereas a higher BMI was associated with higher sAA activity ($UC \geq 0.17$, $t(22) \leq 2.10$, $p \leq 0.047$). As $n = 13$ of the female participants took oral contraceptives, we tested whether the use of oral contraceptives influenced sCort concentrations and sAA activity. Neither sCort concentrations ($UC = 0.19$, $t(14) = 1.595$, $p = 0.133$) nor sAA activity ($UC = 0.18$, $t(14) = 0.297$, $p = 0.771$) were affected by the intake of oral contraceptives.

3. Results

Overall, music episodes accounted for 30% of the daily assessments. Music was listened to more often during the control condition (34%) than during the exam condition (25%), with condition explaining 1.09% of the variance in the frequency of music episodes ($\chi^2 = 33.23$, df = 3, $p \leq 0.001$). The reasons for listening to music were (in descending order): 'activation' (57%), 'relaxation' (47%), 'distraction' (47%), and 'reducing boredom' (46%) with 'relaxation' as reason for music listening being reported significantly more often during the late afternoon and evening than during the morning ($UC = 0.05$, $t(588) = 3.358$, $p \leq 0.001$). On average, the perceived valence of the music was rated as rather positive ($M = 68.89$, SD = 20.66) and the perceived arousal was rated as rather high ($M = 64.86$, SD = 24.97). Data from the MPQ revealed that participants listened to music on average for $M = 2.40$ (SD = 2.02) h per day, and participants rated music as important for their lives ($M = 4.21$, SD = 0.99).

3.1. Is music listening associated with lower stress ratings (Model 1)?

We first examined whether music listening was associated with reduced levels of subjective stress (Model 1a). The unconditional model included only subjective stress as dependent variable at level-1 and gender at level-2, and no music listening. We then specified the following conditional model: Subjective stress levels were modeled as a function of music episodes (yes/no) (β_{1j}) and a residual component (r_{ij}). As all level-1 observations were entered in these analyses, we modeled these analyses as random effects models. At the individual level (level-2), the intercept (β_0) was modeled as a function of gender (γ_{01}) and a residual component (u_0). In line with our expectations, participants displayed lower subjective stress after having listened to music (Table 1, Model 1a). The model fit (calculated as the reduction in deviance from the unconditional model to the model including music episode as a predictor) was significant, with 1.79% of the variance in subjective stress being explained by music episode ($\chi^2 = 15.51$; df = 3; $p = 0.002$). We then modeled sCort concentrations as a function of time point (β_{1j}), music episode (yes/no) (β_{2j}) and a residual component (r_{ij}) at level-1 (Model 1b). At the individual level (level-2), the intercept (β_0) was modeled as function of gender (γ_{01}), body mass index (BMI) (γ_{02}), and a residual component (u_0). There was no association between music episode and sCort concentration. Calculating an identical model with sAA activity as momentary outcome, no associations between music episode and sAA activity were found (Model 1c). Results are presented in Table 1.

3.2. Does the stress-reducing effect of music vary as a function of perceived valence/arousal of the selected music (Model 2)?

In a next step, we analyzed the perceived valence and arousal of the selected music with respect to stress ratings (Model 2). For this purpose, only time points when music was listened to (music episodes) were entered into the

Table 1 Hierarchical linear models predicting repeatedly assessed momentary stress (40 measures) (Model 1a), repeatedly measured salivary cortisol (16 measures) (Model 1b) as well as predicting repeatedly measured salivary alpha-amylase activity (16 measures) (Model 1c) by music episode (Model 1b) using restricted maximum likelihood.

	Model 1a: changes in subjective stress music episode		Model 1b: changes in sCort by music episode		Model 1c: changes in sAA by music episode	
Fixed effects	Unstandardized coefficients	SE (df), *p*	Unstandardized coefficients	SE (df), *p*	Unstandardized coefficients	SE (df), *p*
Intercept level-2	1.17	0.12 (48), *≤0.001*	11.95	0.13 (22), *≤0.001*	10.55	1.18 (22), *≤0.001*
Gender	0.20	0.14 (48), *0.153*	0.34	0.13 (22), *0.012*	−0.04	0.28 (22), 0.875
BMI[1]			−0.02	0.02 (22), *0.425*	0.16	0.16 (22), 0.011
Music episode (0/1)[2]	−0.17	0.06 (49), *0.010*	−0.01	0.01 (24), *0.915*	0.04	0.09 (24), 0.678
Time of day[3]			−0.45	0.04 (24), *≤0.001*		
Random effects	Variance component	SD (df), *p*	Variance component	SD (df), *p*	Variance component	SD (df), *p*
Intercept level-1	0.25	0.50 (47), *≤0.001*	0.05	0.23 (19), *0.012*	0.63	0.80 (19), *≤0.001*
Music episode slope	0.06	0.25 (48), *0.029*	0.02	0.13 (21), *>0.500*	0.00	0.06 (21), 0.447
Residual	0.86	0.93	0.36	0.60	0.55	0.74

[1] BMI was only entered in analyses predicting sCort and sAA.
[2] (0/1): 0 = no music episode, 1 = music episode.
[3] Time of day was only entered in analyses predicting sCort.

analyses. As the number of level-1 observations is already reduced in these analyses we did not model these analyses as random effects models as this would further reduce the number of level-1 and -2 observations. The following conditional model was specified: Subjective stress levels were modeled as a function of perceived valence (β_{1j}) and perceived arousal (β_{2j}) and a residual component (r_{ij}) (Model 2a). At the individual level (level-2), the intercept (β_0) was modeled as a function of gender (γ_{01}) and a residual component (u_0). Neither perceived valence ($UC = -0.00$, $t(526) = -1.378$, $p = 0.169$) nor perceived arousal ($UC = 0.00$, $t(526) = 0.782$, $p = 0.434$) was associated with subjective stress levels. The reduction in deviance of this overall model was not significant ($\chi^2 = 7.89$; df = 4; $p = 0.095$). Concerning sCort concentrations (Model 2b), neither perceived valence ($UC = 0.00$, $t(115) = 0.175$, $p = 0.862$) nor perceived arousal ($UC = 0.01$, $t(115) = 1.453$, $p = 0.149$) was associated with sCort concentrations. Concerning sAA activity (Model 2c), the perceived arousal of the music influenced sAA activity, as music which was rated as high in arousal predicted increased sAA activity ($UC = 0.01$, $t(110) = 2.272$, $p = 0.025$). The overall model explained 3.55% of the variance in sAA. The reduction in deviance was not significant ($\chi^2 = 6.38$; df = 5; $p = 0.270$). There was no association between sAA activity and the perceived valence of the selected music ($UC = -0.00$, $t(110) = -1.679$, $p = 0.096$).

3.3. Does the stress-reducing effect of music vary as a function of reasons for music listening (Model 3)?

In a third conditional model, we analyzed whether specific reasons for music listening accounted for any changes in subjective stress levels (Model 3a). Subjective stress levels were modeled as a function of 'relaxation' (β_{1j}), 'activation' (β_{2j}), 'distraction' (β_{3j}), 'reducing boredom' (β_{4j}), and a residual component (r_{ij}). Each specific reason for music listening was coded as 0/1, with 0 indicating that this reason was not chosen and 1 indicating that this reason was chosen, respectively. At the individual level (level-2), the intercept (β_0) was modeled as a function of gender (γ_{01}) and a residual component (u_0). Only music that was listened to for the reason 'relaxation' yielded lower subjective stress ratings ($UC = -0.45$, $t(524) = -5.430$, $p \leq 0.001$). In an exploratory analysis we examined whether music listening for the reason 'relaxation' only occurred when participants were experiencing particularly high or low levels of stress in advance. In this time-lagged analysis, we could show that there was no association between previous stress levels and music listening for the reason 'relaxation' ($UC = 0.05$, $t(426) = 1.827$, $p = 0.068$). Music that was listened to for the reason 'distraction' was associated with increased subjective stress levels ($UC = 0.35$, $t(524) = 3.652$, $p \leq 0.001$). The reasons 'activation' ($UC = -0.06$, $t(524) = -0.717$, $p = 0.474$) and 'reducing boredom' ($UC = -0.14$, $t(524) = -1.535$, $p = 0.125$) showed no associations with subjective stress levels. In this model, the predictor 'relaxation' explained 6.50% of the variance in stress levels. The reduction in deviance (from the model including 'activation', 'distraction' and 'reducing boredom' as predictors to the model additionally including 'relaxation' as predictor) was significant ($\chi^2 = 44.43$; df = 6; $p \leq 0.001$).

Concerning sCort concentrations (Model 3b), it was shown that in accordance with the results on self-reported stress, music that was listened to for the reason 'relaxation' yielded lower sCort concentrations ($UC = -0.48$, $t(113) = -3.513$, $p \leq 0.001$). In this model, the predictor 'relaxation' explained 12.44% of the variance in sCort, and the reduction in deviance (from the model including 'activation', 'distraction' and 'reducing boredom' as predictors to the model additionally including 'relaxation' as predictor) was significant ($\chi^2 = 26.54$, df = 7, $p \leq 0.001$). Concerning sAA (Model 3c), reasons for music listening were not associated with sAA activity ($UC < 0.28$, $t(108) < 1.789$, $p > 0.076$).

3.4. Stress intensity across the two conditions

There was a significant difference between the levels of perceived stress during the two conditions ($t(2050) = 14.46$, $p \leq 0.001$). Perceived stress levels were higher during the exam condition, with 9.29% of the variance in subjective stress levels being explained by condition ($\chi^2 = 204.47$, df = 3, $p < 0.001$). Cortisol concentrations differed between the two conditions ($t(363) = 2.13$, $p = 0.034$), with higher sCort concentrations during the exam condition, with 1.34% of the variance in sCort being explained by condition ($\chi^2 = 18.81$, df = 4, $p = 0.001$). There was no difference in sAA activity ($t(355) = 1.37$, $p = 0.172$) between the control and exam condition.

3.5. Does the stress-reducing effect of music vary as a function of stress intensity (Model 4)?

We analyzed the stress-reducing effect of music listening as a function of condition (Model 4). Therefore, the following conditional model was specified: Subjective stress levels were modeled as a function of condition (β_{1j}), music episode (yes/no) (β_{2j}), condition × music episode (β_{3j}), and a residual component (r_{ij}). At the individual level (level-2), the intercept (β_0) was modeled as a function of gender (γ_{01}) and a residual component (u_0). A marginally significant interaction of condition × music episode emerged ($UC = 0.17$, $t(1836) = 1.903$, $p = 0.057$). In this model, the predictors condition and condition × music episode accounted for 8.80% of the variance in stress in addition to music episodes alone. The reduction in deviance (from including only music episode in the model to including condition and condition × music episode in the model) was significant ($\chi^2 = 178.140$, df = 7, $p \leq 0.001$). Although the interaction term did not reach statistical significance with a pre-set alpha level of 0.05, we further investigated the nature of this interaction effects as McClelland and Judd (1993) state that detecting interactions in field studies is statistically more difficult than in experimental studies. Interaction terms were interpreted in accordance with Preacher et al. (2006), and music episode was considered the focal predictor, while condition was considered the moderator. Results are presented in Fig. 1. During the control condition, the relationship between music listening and subjective stress was significant ($\gamma_{1|0} = -0.1711$, $t(49) = -2.3862$, $p = 0.021$), whereas during the exam condition, the relationship between music listening and subjective stress was not significant ($\gamma_{1|1} = 0.002$, $t(49) = 0.0258$, $p = 0.980$).

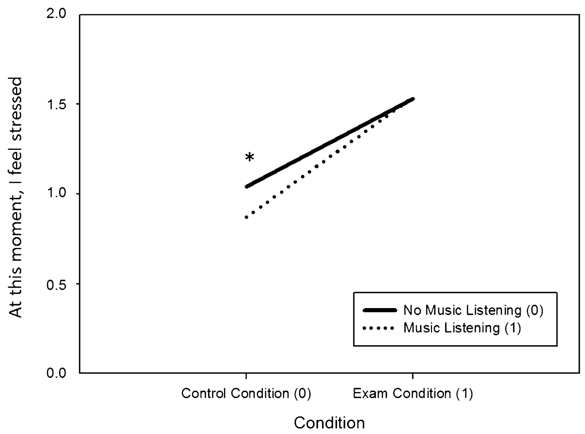

Figure 1 Mean stress level as a function of music listening (0/1) and condition (0/1). *Note*: * $p \leq 0.05$.

We then analyzed whether the effects of music listening on sCort varied as a function of condition. Concerning the number of music episodes, there was no significant interaction of condition × music episode ($UC = 0.01$, $t(329) = 0.050$, $p = 0.960$). With regard to sAA, there was no significant interaction of condition × music episode ($UC = 0.26$, $t(344) = 1.558$, $p = 0.120$).

4. Discussion

We sought to investigate the stress-reducing effect of music listening in daily life. Results suggest that mere music listening was associated with lower subjective stress levels. Nonmusical context factors contributed to the stress-reducing effect of music listening: Whereas the perceived valence of the selected music did not show any associations with stress parameters, music which was perceived as low in arousal was associated with lower sAA activity. The stress-reducing effect (attenuated subjective stress levels and concentrations of sCort) was particularly evident when music was listened to for the specific reason of 'relaxation' in the late afternoon and evening. There was an interaction between music and stress intensity insofar as music listening was only associated with lower subjective stress levels during the control condition.

4.1. Music listening reduces stress in daily life

Mere music listening had a profound effect on subjective stress levels, but it did not directly affect either HPA axis or ANS activity. At first glance, this appears to be in line with previous experimental studies, in which music listening reduced subjective stress but not its physiological correlates (e.g., DeMarco et al., 2011). However, our results provide evidence for the idea that different measures of stress may respond to different characteristics of music: sCort concentrations were lowest when the reason for music listening was 'relaxation', independent of its valence or arousal. The reverse pattern was true for sAA, which was lowest when participants listened to music that was perceived as low in arousal, independent of the reasons for music listening.

Relating these findings to the existing literature, to the best of our knowledge, only one study has measured sCort and sAA simultaneously: In a laboratory study (Thoma et al., 2013), we showed that music listening prior to a stressor differentially affected HPA and ANS activity as well, with relaxing music accelerating ANS, but not HPA, recovery from a stressor. This is in accordance with our finding that the arousal of the music affected sAA but not sCort. Based on an overview of experimental studies, Chanda and Levitin (2013) suggest that relaxing music is usually associated with a decrease in cortisol. In our study, a reduction in cortisol was associated not with the *perception* of music as relaxing, but rather with the *reason* of 'relaxation'. Thus, our findings support the importance of a multi-system assessment of stress, as music listening differentially affects stress physiology.

Furthermore, our results shed light in the role of nonmusical context factors regarding the stress-reducing effect of music listening. This clearly extends notions from common models concerning the mechanisms of the effects of music on health. We recently proposed that the health-beneficial effects of music listening may be mediated by a reduction in stress (Thoma and Nater, 2011). Our results add to this hypothesis the importance of nonmusical context factors, especially reasons for music listening.

4.2. Relaxation as a reason for music listening is associated with the stress-reducing effect of music listening

It is well acknowledged that people listen to music in order to manage their emotions. Juslin et al. (2008) hypothesized that it is the reasons for listening to music which might explain the effects which music exerts. Our results provide empirical evidence that reasons for music listening, here 'relaxation', in conjunction with the time of day are relevant in the context of stress reduction. Although music listening for the reason 'relaxation' mainly occurred in the late afternoon and evening, when concentrations of sCort are generally lower, we could show that music listening for the reason 'relaxation' was associated with a reduction in stress independent of the previously stated stress intensity. However, as music listening was most often reported in the late afternoon and evening, it remains open to further investigation whether the time of day might be relevant to the stress-reducing effect of music listening. This is especially relevant as there is so far no sound knowledge on which timing of music listening relative to a stressor is best. Results vary depending on whether participants listen to music prior to or after a stressor (Khalfa et al., 2003; Thoma et al., 2013): concerning effects of music listening on HPA axis activity, listening to music after a stressor seemed to be more effective (Khalfa et al., 2003), whereas listening to music prior to a stressor positively affected ANS activity (Thoma et al., 2013). This somehow mirrors the findings in our study which show that music listening for the reason of relaxation, which mainly occurred in the evening, had a beneficial effect on subjective stress levels and HPA axis activity. Therefore, our results give rise to the assumption that time of day is relevant in designing music interventions with probably most profound effects when music listening occurs in the late afternoon and evening.

Interestingly, in our study, listening to music for the reason 'distraction' was found to increase stress. This finding is worthy of attention, as it is discussed in the literature that music has beneficial effects by distracting people from aversive states (Bernatzky et al., 2001; Chanda and Levitin, 2013; Mitchell et al., 2007). However, such a beneficial effect has been predominantly examined in the context of acute stressors. Fancourt et al. (2014) suggest that effects of music may vary depending on whether people are experiencing acute versus chronic stress. Thus, one possible explanation for our finding is that music listening for the reason 'distraction' may be beneficial in the context of acute stressors but not under conditions of longer-lasting stress episodes, as reflected in our study by the exam condition.

At first glance, the finding concerning the limited stress-reducing effect under the experience of heightened stress seems to be in line with laboratory studies (for a review, see Pelletier, 2004). However, we were able to show that people listened to music less often in the exam condition, thus demonstrating that under heightened stress, music-listening behavior changes. It might be argued that participants did not find the time to listen to music while preparing for their exams. Therefore, we cannot conclude that music listening is not effective under the experience of heightened stress.

4.3. Limitations

Although this is the first study to investigate the effects of music listening on both subjective and physiological measures of stress in daily life, our findings need to be considered in the light of a number of limitations: We concurrently measured sAA and sCort at the same time, even though sAA and sCort underlie a different time course (Engert et al., 2011). However, in order to assess the direct effects of music listening on stress markers, it is necessary to collect sAA and sCort samples closer in time to when actual music listening occurred, for example by means of event-based sampling methods. Furthermore, only a subsample of participants provided saliva samples on two consecutive days during each condition. Therefore, it is possible that the proportion of variance in sCort and sAA through music listening might be overestimated. Although the subsample did not differ from the total sample in music-listening behavior and stress perception, these findings need to be corroborated in a larger sample. Furthermore, we assessed subjective stress with only one item. Although this is in accordance with Elo et al. (2003), it has to be kept in mind that the reliability of this stress measure might be lower than a more comprehensive assessment of subjective stress. With respect to the assessment of music-listening behavior, we only assessed *whether* music listening had occurred since the last assessment. Therefore, we do not have information on the duration and exact timing of the music listening. However, this information could be potentially relevant, especially due to the aforementioned specific reaction patterns of sAA and sCort to music listening. Furthermore, we did not collect data on the exact kind of music that was listened to with respect to genre, valence and arousal. However, 'objective' data on music listening might be necessary in order to further shed light on the health-beneficial effects of music listening in daily life. Concerning our study population, our inclusion criteria might have led to a selection bias as we constrained age to a range of 18 to 35 and further had an over-representation of females in our study. Also, our study population is quite homogenous when it comes to the educational background. All this limits the generalizability to the general population.

4.4. Implications for the use of music in both non-clinical and clinical contexts

Our results suggest that the stress-reducing effects of music listening are unfolded beyond the scope of experimental contexts with music listening differentially affecting stress physiology. The mechanisms behind the stress-reducing effect of music listening seem to vary between experimental contexts and daily life. In daily life, it seems to be the reasons for music listening that are associated with a stress-reducing effect of music listening. Particularly due to the fact that music is very popular, cost-effective and easily applicable in daily life, it seems promising to use music in daily life as a strategy for stress reduction.

Clinical populations seem to benefit from music therapy (Hanser, 2010). Whereas music therapy is a complex procedure involving a professional clinician, the mere listening to music in daily life might be a promising adjuvant treatment option for patients. As our study shows, it is not only music per se that has these stress-reducing effects; rather, a number of contextual factors also have to be considered in order to achieve maximum efficacy as an intervention. Interventions for the purpose of stress reduction should therefore concentrate on manipulating intentions behind music listening rather than music selection, and the timing of music listening relative to a stressor should be kept in mind.

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The funding sources had no role in the design of the study, data collection and analysis, or drafting of the manuscript.

Conflict of interest statement

The authors declare no financial interest related to the study.

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Paper III

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The stress-reducing effect of music listening varies depending on the social context

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Short title: Stress, music listening, and social context

Abstract

Objective: Given that music listening often occurs in a social context, and given that social support can be associated with a stress-reducing effect, it was tested whether the mere presence of others while listening to music enhances the stress-reducing effect of listening to music.

Methods: A total of 53 participants responded to questions on stress, presence of others, and music listening five times per day (30 minutes after awakening, 1100h, 1400h, 1800h, 2100h) for seven consecutive days. After each assessment, participants were asked to collect a saliva sample for the later analysis of salivary cortisol (as a marker for the hypothalamic-pituitary-adrenal axis) and salivary alpha-amylase (as a marker for the autonomic nervous system).

Results: Hierarchical linear modeling revealed that music listening per se was not associated with a stress-reducing effect. However, listening to music in the presence of others led to decreased subjective stress levels, attenuated secretion of salivary cortisol, and higher activity of salivary alpha-amylase. When listening to music alone, music that was listened to for the reason of relaxation predicted lower subjective stress.

Conclusion: The stress-reducing effect of music listening in daily life varies depending on the presence of others. Music listening in the presence of others enhanced the stress-reducing effect of music listening independently of reasons for music listening. Solitary music listening was stress-reducing when relaxation was stated as the reason for music listening. Thus, in daily life, music listening can be used for stress reduction purposes, with the greatest success when it occurs in the presence of others or when it is deliberately listened to for the reason of relaxation.

Keywords: daily life, ambulatory assessment, music listening, presence of others, stress

1 Introduction

Music listening is a popular activity of daily life (North et al., 2004). As there is accumulating evidence that music listening in daily life is associated with beneficial effects for well-being and health, it is of utmost importance to study the effects of music listening in daily life, i.e. in a setting characterized by high ecological validity. Sloboda et al. (2001) were pioneers in this area of research in that they conducted the first ecological momentary assessment study which directly investigated participants and their music listening behaviors in their daily lives. In addition to descriptive data on situations in which music was listened to, Sloboda et al. (2001) were able to show that music listening in daily life was associated with beneficial effects on mood. This finding is in line with other studies set in daily life, which found that music listening was associated with the experience of positive emotions (Juslin et al., 2008; van Goethem and Sloboda, 2011). Furthermore, studies not only point towards beneficial effects for mood and well-being in healthy populations, but also towards favorable effects on various disease states (Batt-Rawden et al., 2005; Linnemann et al., 2015b; Särkämö et al., 2008).

However, the underlying psychophysiological mechanisms for these beneficial effects remain unclear. We hypothesize that beneficial effects of music listening on health are mediated by a psychophysiological stress reduction (Thoma and Nater, 2011). This is in line with evidence from recent neuroimaging studies. Music-evoked emotions are associated with activity in core emotion networks (Koelsch, 2014). Two brain structures that are involved in music-induced emotions are the hippocampus and the amygdala (Koelsch, 2014), which are both known to be involved in regulating the hypothalamic-pituitary-adrenal (HPA) axis (Tsigos and Chrousos, 2002). The HPA axis is one of the prominent stress systems in the body. An activation of this axis can be indirectly measured by the secretion of the hormone cortisol (Hellhammer et al., 2009). Indeed, music listening (in experimental contexts) has previously been linked to the secretion of cortisol, although the reported results are inconsistent (for an overview, see: Chanda and Levitin, 2013; Kreutz et al., 2012; Thoma and Nater, 2011). For example, studies investigating the effects of relaxing music on HPA axis activity either found reduced cortisol secretion or no effect (Chanda and Levitin, 2013). When studying the effects of stimulating music, both lower and higher cortisol secretion have been found (Chanda and Levitin, 2013). These inconsistencies might partly arise from heterogeneous methodologies, as the studies vary with regard to who had control over choice of music (self-selected versus experimenter-selected) and what kind of music was listened to (Chanda and Levitin, 2013). Another prominent stress-sensitive system in the body is the autonomic nervous system (ANS), which has also been implicated in mediating music-induced physiological changes (Hodges, 2011). Its activation can be indirectly measured by the secretion of the salivary enzyme alpha-amylase (Nater and Rohleder, 2009). Using this enzyme as an autonomic stress marker, subjects listening to music prior to stress have been shown to recover faster after exposure to a psychosocial stressor as compared to non-music control conditions (Thoma et al., 2013) .

However, most of the findings examining mechanisms underlying the beneficial effects of music listening were gathered in experimental settings. The number of studies set in daily life is still limited. We were able to show that music listening in daily life affects psychophysiological stress as measured by salivary cortisol and salivary alpha-amylase (Linnemann et al., 2015a). In this study, different features of the music itself (e.g., valence and arousal of the music) but also nonmusical context factors (e.g., reasons for music listening) contributed to the stress-reducing effect of listening to music (Linnemann et al., 2015a). In particular, reasons for music listening predicted stress reduction. Listening to music for the reason of relaxation reduced both subjective and physiological parameters of stress in a sample of healthy participants (Linnemann et al., 2015a), and it increased control over pain in patients with fibromyalgia (Linnemann et al., 2015b).

As promising as these results might be, so far, most of the research on the stress-reducing effect of music listening focused on individuals listening to music in solitude. However, the social context is especially relevant, as music listening is thought to fulfill social functions (Boer and Abubakar, 2014; Hargreaves and North, 1999; Koelsch, 2013), and research addressing this factor is still in its infancy (Hargreaves and North, 1999). Furthermore, most of the studies concentrated on musical group activities (e.g. singing; Valentine and Evans, 2001), leaving the question of any beneficial effect of mere music listening unanswered. There is evidence from the literature that at least some of the beneficial effects of music listening are closely linked to its social functions. In a questionnaire study, Boer and Abubakar (2014) showed that listening to music with peers was positively associated with continuous measures of well-being and social cohesion. In an experimental study, in which participants were seated next to each other in rocking chairs and were asked to rock at a comfortable rate, Demos et al. (2012) found that those participants who synchronized their rate of rocking to music (as opposed to visual information) felt more connected to the other person. Studies set in daily life found that music listening in the presence of others evoked more positive emotions than music listening in solitude (Juslin et al., 2008). Consequently, there is evidence that in the presence of others, the beneficial effects of music on emotional well-being and social cohesion are enhanced, but little is known about whether this effect also translates into enhancing the stress-reducing effect of listening to music.

Empirical evidence on stress (beyond the scope of music listening) consistently shows that social support has a stress-buffering function (Cohen and Wills, 1985).Translating these findings to the stress-reducing effect of music listening, it seems quite reasonable to assume a relevant role of the social context of listening to music. Experimental studies investigating the social context of musical activities focus on synchronization between the actors (e.g., Mercadie et al., 2014), but the question arises whether the mere presence of others can yield beneficial effects as well. Although there is accumulating evidence from the stress literature that the presence of others affects stress levels (for a review, see: Seeman and McEwen, 1996), there is no evidence regarding whether this can be generalized to the stress-reducing effect of music listening. Furthermore, it does not seem to be the mere presence of others that is stress-reducing per se; rather, the familiarity of the people present may play a crucial role in this effect (Allen et al., 1991). Kissel (1965) showed that the stress-reducing effect of the presence of others is even more profound if friends are present in contrast to strangers. Kirschbaum et al. (1995) found that this effect might be sex-specific, with men benefitting more from partner support than women. According to Ditzen et al. (2007), the kind of support that is provided appears to be important, as supporters who performed a massage were more effective than supporters who provided verbal support. However, all of these results were mainly found in laboratory studies set in highly artificial surroundings with low ecological validity. The question arises whether listening to music in the presence of others can act as a source of support, and whether it enhances the stress-reducing effect of listening to music.

1.1 Research Question

It is hypothesized that the presence of others while listening to music enhances the stress-reducing effect of listening to music (Hypothesis 1). This hypothesis is tested by means of an ambulatory assessment design encompassing both subjective stress as well as parameters of biological stress-responsive systems. Furthermore, it is hypothesized that the familiarity of the people present moderates this effect, with further attenuated stress levels when music is listened to in the presence of friends (Hypothesis 2). As listening to music for the reason of relaxation was found to be predictive of the stress-reducing effect of listening to music in previous studies, it was tested, in an exploratory manner, whether this stress-reducing effect of listening to music for the reason of relaxation varies depending on the presence of others.

2 Method

2.1 Participants

Participants were recruited from various sources, such as emails sent to university mailing lists and a notice on a bulletin board for psychological studies. A total of 53 healthy young subjects (32 female, 21 male) participated in the study. Participants' age ranged from 20 to 32 years with a mean of $\bar{x}$ = 23.32 (SD = 3.08) years. All participants had a BMI < 30, were either non-smokers or smoked less than five cigarettes per week, did not consume drugs (no consumption of cannabis within the last two weeks, no consumption of any other psychotropic substances within the last four weeks), did not take any medication (except for hormonal contraceptives), and had no chronic somatic or psychiatric disease (according to self-reports based on the Patient Health Questionnaire (PHQ; Löwe et al., 2002)). They received either 40 Euro or course credit as reimbursement. The study has been approved by the local IRB.

2.2 Design

The study was designed as an ambulatory assessment study (Fahrenberg, 1996). Ambulatory assessment refers to studies set in daily life that encompass self-reports, behavior records, and/or physiological measurements (Fahrenberg et al., 2007). Examining participants repeatedly in their daily life while they are going about their daily routine allows recall bias to be minimized and ecological validity to be maximized (Shiffman et al., 2008). Therefore, it is possible to examine the dynamics of variables of interest in the participants' natural habitat (Shiffman et al., 2008; Smyth and Stone, 2003). At the same time, studies set in daily life bring challenges. As there is no random assignment to a condition, the possibility to draw causal conclusions is limited (Smyth and Stone, 2003). Furthermore, data quality is dependent on compliance, which cannot be as rigorously controlled for in daily life compared to laboratory settings (Smyth and Stone, 2003). Nevertheless, despite higher ecological validity and lower internal validity, Csikszentmihalyi and Larson (1987) provide evidence that the repeated assessment of mental states in daily life allows the fluctuations of psychological states to be captured close to the time of occurrence. To ensure the best possible reliability and validity of salivary stress markers obtained in the field, we took a two-pronged approach. First, we carefully instructed our participants on what to do and what not to do immediately before collection of samples and asked them to freeze the samples as soon as possible. Second, we assessed time of day, smoking, and food intake as sources of intraindividual variance.

2.3 Procedure

Participants were screened for eligibility criteria via a telephone-based interview. In the case of eligibility, participants were invited to an introductory session during which they received standardized information about the study, gave informed consent, and were familiarized with handling a pre-programmed iPod touch®. All participants received a study manual in which all items occurring in this study were explained in detail. Furthermore, all participants completed one trial assessment in the presence of the study staff in order to ensure that all items were properly understood. Participants were asked to carry the iPod touch® with them for the following seven consecutive days. Each day, they were asked to complete six assessments. The first assessment was triggered by the participants themselves immediately after awakening. As this assessment did not include any items on music listening, it will not be considered further. Subsequent assessments were triggered by the pre-programmed iPod touch® 30 minutes after the first assessment and at 1100h, 1400h, 1800h, and 2100h. Additionally, participants were asked to collect a saliva sample at each assessment.

2.4 Measures

2.4.1 Stress

Stress was assessed using indicators for both the experience of subjective stress and for physiological markers of stress.

Subjective stress levels: Momentary subjective stress levels were measured using the item 'At this moment, I feel stressed', which could be answered on a 5-point Likert scale ranging from 0 to 4. Low scores indicate low levels of stress and high scores indicate high levels of stress, respectively.

Physiological markers of stress: Salivary cortisol (sCort) and salivary alpha-amylase (sAA) were concomitantly measured. Participants were asked to collect whole saliva using the SaliCap® system (IBL, Hamburg, Germany). sCort levels were measured using a commercially available enzyme-linked immunoassay (IBL, Hamburg, Germany). sAA activity was measured using a kinetic colorimetric test and reagents obtained from Roche (Fa. Roche Diagnostics, Mannheim, Germany). Inter- and intraassay variance was below 10.00% for both sAA and sCort.

2.4.2 Presence of others (while listening to music)

If music listening had occurred since the last assessment, participants had to indicate retrospectively whether they were alone, in the presence of friends, or in the presence of acquaintances while listening to music. All participants were given a standardized definition of 'presence of others while listening to music'. In line with the description provided in the study manual, participants were asked to refer to music listening in the presence of others whenever other people were around when they were listening to music. They were asked to state the mere presence of others while listening to music independently of interacting with others. Based on Juslin et al. (2008), who showed that the options 'being alone', 'being with a partner or close friend', and 'being with several friends or acquaintances' accounted for

75% of the situations captured in their ambulatory assessment study, we decided to use these three response options.

Additionally, participants were asked to state whether other people were present when the actual assessment was triggered. This information was assessed as a control variable in order to rule out that changes in stress were due to the mere presence of others at the moment the assessment was triggered. This is in line with the known association between the presence of others and stress (Seeman and McEwen, 1996). Therefore, by controlling for the presence of others when the assessment was triggered, we were able to examine whether the presence of others while listening to music affects stress in addition to the mere presence of others when the actual assessment was triggered and in addition to the effect of music listening.

2.4.3 Items on music listening

At each assessment, participants indicated whether they had listened to music since the last assessment. If they had done so, additional items on music listening followed. Based on the current evidence on the stress-reducing effect of music listening, participants were asked to complete items regarding the characteristics of the music by indicating the perceived valence of the music (visual analogue scale (VAS) ranging from sad (0) to happy (100)) (Sandstrom and Russo, 2010) and the perceived arousal of the music (VAS ranging from 0 (relaxing) to 100 (energizing)) (Khalfa et al., 2003). Subsequently, they indicated liking for the music on a scale ranging from 0 (not at all) to 100 (very much) (Stratton and Zalanowski, 1984) and were asked whether they had control over choice of music (yes/no) (Chanda and Levitin, 2013), and whether they had listened to music deliberately (Linnemann et al., 2015a). Then, reasons for music listening were assessed (Linnemann et al., 2015a) with participants choosing their main reason for music listening from among ‘relaxation’, ‘activation’, ‘distraction’, and ‘reducing boredom’. Finally, participants had to indicate the source of music listening (MP3 player, television/radio, stereo equipment, live music, public speaker) (Juslin et al., 2008). All participants received standardized instructions concerning these options. They were provided with a manual in which all items were described in detail and each response option was carefully described.

2.5 Data Analysis

Analyses are based on hierarchical linear modeling (HLM) (Raudenbush et al., 2004). Hypothesis testing was conducted in accordance with Woltman et al. (2012). The interpretation of interactions was conducted as recommended by Preacher et al. (2006). P-values of ≤ .05 were considered significant. Unstandardized coefficients (UC) and standard errors are presented.

Using HLM, both unconditional and conditional models were specified. The unconditional model only included the outcome variable (subjective stress, sCort, or sAA, respectively) and control variables (gender, BMI, presence of others at the moment of assessment, control over choice of music (self-selected vs. not self-selected), liking for music, valence, arousal, reasons for music listening). The conditional model was specified by adding the variable of interest, that is, the presence of others while listening to music and the interaction of 'presence of others when the assessment was triggered × presence of others while listening to music'. Level 1 comprised variables that were assessed repeatedly, whereas level 2 (individual level) comprised trait variables that were assessed only once. Thus, at level 1, the intercept was modeled as a function of presence of others at the moment the assessment was triggered (γ_{10}), control over choice of music (γ_{20}), liking for music (γ_{30}), perceived valence of the music (γ_{40}), perceived arousal of the music (γ_{50}), relaxation (γ_{60}), activation (γ_{70}), distraction (γ_{80}), reducing boredom (γ_{90}), presence of others while listening to music (γ_{100}), interaction 'presence of others when the assessment was triggered × presence of others while listening to music' (γ_{110}). At the individual level (level 2), the intercept (β_0) was modeled as a function of gender (γ_{01}) and a residual component (u_0). In analyses concerning physiological markers of stress, body mass index (BMI) was additionally entered at the individual level due to its known association with HPA axis regulation (Champaneri et al., 2013).

A representative formula is depicted here:

Unconditional model:

$$\textit{Subjective stress}_{ij} = \gamma_{00} + \gamma_{01}*\textit{gender}_j + \gamma_{10}*\textit{presence of others at the moment the assessment was triggered} + \gamma_{20}*\textit{control over choice of music}_{ij} + \gamma_{30}*\textit{liking for music}_{ij} + \gamma_{40}*\textit{valence}_{ij} + \gamma_{50}*\textit{arousal}_{ij}\ \ \gamma_{60}*\textit{relaxation}_{ij} + \gamma_{70}*\textit{activation}_{ij} + \gamma_{80}*\textit{distraction}_{ij} + \gamma_{90}*\textit{reducing boredom}_{ij} + u_{0j} + r_{ij}$$

Conditional model:

*Subjective stress$_{ij}$ = γ_{00} + γ_{01}*gender$_j$ + γ_{10}*presence of others at the moment the assessment was triggered$_j$ + γ_{20}*control over choice of music$_{ij}$ + γ_{30}*liking for music$_{ij}$ + γ_{40}*valence$_{ij}$ + γ_{50}*arousal$_{ij}$ γ_{60}*relaxation$_{ij}$ + γ_{70}*activation$_{ij}$ + γ_{80}*distraction$_{ij}$ + γ_{90}*reducing boredom$_{ij}$ + γ_{100} * presence of others while listening to music +γ_{110}*interaction$_{ij}$ + u_{0j}+ r_{ij}*

The comparison between these models was undertaken by means of χ^2-square statistics, which compares the reduction in deviance as a measure of model fit. As an indicator of explained variance, pseudo-R^2 is reported, calculated in accordance with the formula (σ^2(unconditional growth model) − σ^2(subsequent model))/ σ^2(unconditional growth model) (Singer and Willett, 2003).

As subjective stress reports ($UC = -0.06$, $t(1623) = -2.692$, $p = 0.007$), the secretion of sCort ($UC = -0.37$, $t(1623) = -28.425$, $p \leq 0.001$), and the activity of sAA ($UC = 0.22$, $t(1623) = 11.565$, $p < 0.001$) varied throughout the day, all analyses concerning music listening (yes/no) and stress controlled for time of day on level-1. However, for the sake of consistency with previous studies (Linnemann et al., 2015a), a time predictor was not entered into analyses in which only music listening episodes were included. As music listening was most often reported during the afternoon/evening ($UC = 0.06$, $t(1878) = 7.984$, $p \leq 0.001$), it can be assumed that the influence of diurnal variations was kept to a minimum in these analyses. Biological data were checked for normality using the Kolmogorov-Smirnov test. Both sCort ($D(2082) = 6.099$, $p \leq 0.001$) and sAA ($D(2058) = 7.561$, $p \leq 0.001$) significantly differed from a normal distribution and were therefore logarithmized using the formula ln (x) + 10.

3 Results

Music listening was reported at 38.5% of the total time points (so-called music episodes). Music was listened to in the presence of others in 35.0% of these music episodes. When listening to music in the presence of others, music was more often listened to in the presence of friends (64.3%) than acquaintances (35.7%). Furthermore, music listening behavior differed depending on the presence of others when listening to music. When listening to music alone, liking for music was higher and music was significantly more often listened to deliberately and self-chosen, and the reasons were more often relaxation or reducing boredom. When listening to music in the presence of others, the valence of the music was rated as more positive. Moreover, the source of the music varied depending on the presence of others, with music being listened to more often using an MP3 player or television/radio when listening to music alone. By contrast, when listening to music in the presence of others, live music or music at a public place was most often listened to. An overview of all music listening items and the exact inferential statistics can be found in Table 1.

The mean stress level experienced over the whole assessment duration was $\bar{x} = 1.25 \pm 1.01$. When listening to music alone, the mean stress level was $\bar{x} = 1.27 \pm 1.02$, whereas when listening to music in the presence of others, the mean stress level was $\bar{x} = 1.04 \pm 1.01$. This difference was significant (t = 2.717, df = 652, $p = 0.007$). At 47.5% of the total time points, participants reported being in the presence of others when the assessment was triggered.

3.1 The presence of others while listening to music enhances the stress-reducing effect of listening to music (Hypothesis 1)

Mere music listening was not associated with any parameters of stress (subjective stress levels: $UC = -0.05$, $t(1622) = -1.100$, $p = 0.271$; sCort: $UC = -0.02$, $t(1622) = -0.660$, $p = 0.510$; sAA: $UC = 0.03$, $t(1622) = 0.737$, $p = 0.461$). However, when considering the presence of others, the following pattern of results emerged (see Table 2): neither the presence of others when the assessment was triggered nor the presence of others while listening to music were associated with subjective stress reports. However, the 'presence of others when the assessment was triggered x presence of others while listening to music' interaction was significant with 2.23 % of variance explained in subjective stress ($\chi^2 = 59.85$; $df = 13$; $p \leq 0.001$). This interaction term may be interpreted in the sense that subjective stress was lowest when both circumstances were met, that is being in the presence of others when the assessment was triggered and having listened to music in the presence of others ($\gamma_{1|1} = -0.4624$, $t(582) = -2.8633$, $p = 0.0043$) (see Figure 1).

Table 1 Statistics on music listening items

	All music episodes		Listening to music alone		Listening to music in the presence of others		χ^2 square statistics[1]
	n	%	n	%	n	%	p value
Music listening (0/1) [2]	649	38.5	422	65.0	227	35.0	-
Deliberate music listening (0/1)[2]	340	52.4	250	73.5	90	26.5	<0.001
control over choice of music (0/1) [3]	362	55.8	301	83.1	61	16.9	<0.001
Reason relaxation (0/1) [2]	136	21.0	106	77.9	30	22.1	<0.001
Reason activation (0/1) [2]	167	25.7	111	66.5	56	33.5	0.339
Reason distraction (0/1) [2]	108	16.6	75	69.4	33	30.6	0.161
Reason reducing boredom (0/1) [2]	38	5.9	31	81.6	7	18.4	0.017
Source: MP3 Player (0/1) [2]	120	18.5	103	86.6	16	13.4	<0.001
Source: TV/radio (0/1) [2]	218	33.6	118	54.1	100	45.9	<0.001
Source: stereo (0/1) [2]	272	41.9	181	66.5	91	33.5	0.218
Source: Live Music (0/1) [2]	5	0.8	0	0.0	5	100.0	0.015
Source: Public Place (0/1) [2]	15	2.3	4	26.7	11	73.3	0.003
	Mean	SD	Mean	SD	Mean	SD	t statistic[4]
Liking for music (0-100)[5]	74.99	20.67	77.71	18.65	69.55	23.30	<0.001
Valence (0-100)[6]	64.58	21.31	61.99	21.87	68.74	19.60	<0.001
Arousal (0-100)[7]	63.15	23.45	61.99	22.79	64.89	24.16	0.129

Note. [1] analyses are based on contingency tables comparing the frequency of music listening in the presence of others to the frequency of music listening alone, [2] (0/1): 0 = no, 1 = yes (note: the frequency of 'yes' is depicted), [3] 0 = not self-selected, 1 = self-selected (note: the frequency of self-selected music is depicted), [4] analyses are based on hierarchical linear modeling testing whether the presence of others while listening to music explains variance in liking for music, valence, and arousal, respectively, [5] VAS ranging from 0 (not at all) to 100 (entirely), [6] VAS ranging from 0 (sad) to 100 (happy), [6] VAS ranging from 0 (relaxing) to 100 (energizing)

Concerning the secretion of sCort the following results emerged: both the presence of others when the assessment was triggered as well as the presence of others while listening to music were associated with lower secretion of sCort. The presence of others while listening to music additionally explained 2.25 % of variance in sCort (χ^2 = 70.91; *df* = 14; $p \leq 0.001$).

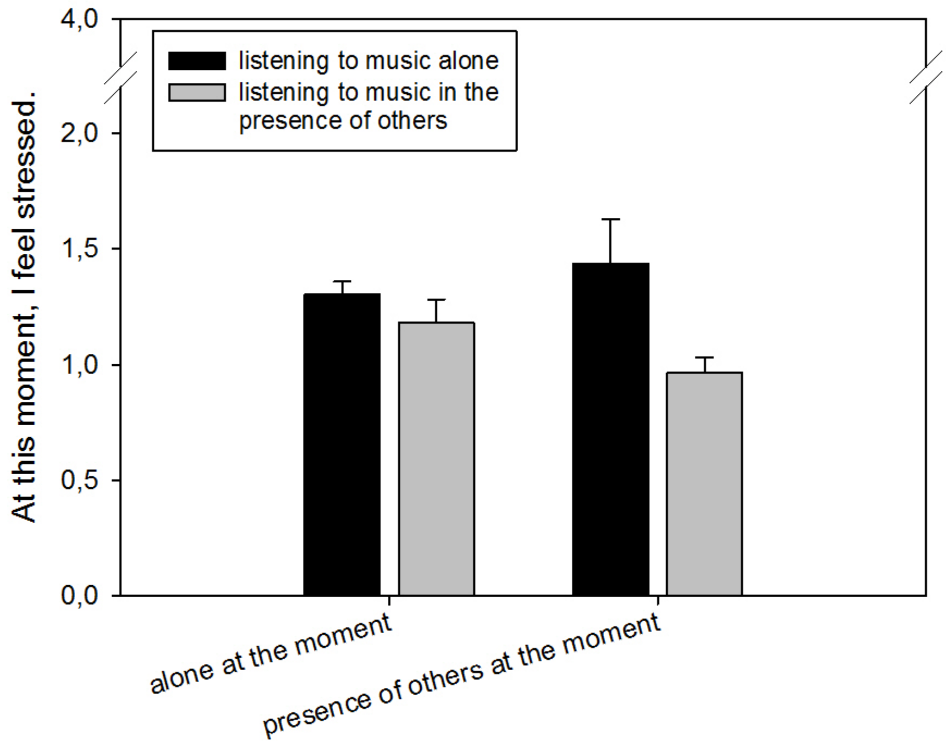

Figure 1: Mean stress level as a function of presence of the others at the moment of assessment (0/1) and presence of others while listening to music (0/1). Note: error bars represent standard error of the mean

Concerning the activity of sAA, the presence of others while listening to music was associated with higher activity of sAA, whereas there was no such effect for the presence of others when the assessment was triggered. Furthermore, the presence of others while listening to music additionally explained 2.91% of variance in the activity of sAA (χ^2 = 70.57; *df* = 14; $p \leq 0.001$)

With regard to the control variables, music that was listened to for the reason of relaxation was associated with lower subjective stress levels, whereas music that was listened to for the reason of activation was associated with higher sCort secretion. Music that was low in arousal was associated with lower sAA activity. Control over choice of music was associated with sCort secretion, with music that was self-chosen being associated with lower sCort secretion. At the same time, liking for music was associated with higher sCort secretion (see Table 1 for details).

3.2 The familiarity of the people present moderates this stress-reducing effect, with further attenuated stress levels when music is listened to in the presence of friends (Hypothesis 2)

The familiarity of the people present (friends versus acquaintances) did not further enhance the stress-reducing effect of listening to music in the presence of others (subjective stress levels: $UC = -0.31$, $t(171) = -0.847$, $p = 0.987$; sCort: $UC = 0.02$, $t(171) = 0.064$, $p = 0.949$; sAA: $UC = 0.06$, $t(171) = 0.212$, $p = 0.832$). However, only N = 44 participants were entered into these analyses as nine participants always listened to music alone.

3.3 Exploratory Analysis: Does the stress-reducing effect of listening to music for the reason of relaxation vary depending on the presence of others?

As expected, music listening for the reason of relaxation predicted lower subjective stress levels (see Table 2). It was therefore tested, in an exploratory manner, whether the stress-reducing effect of listening to music for the reason of relaxation varies depending on the presence of others. For this purpose, an interaction term ‘relaxation as reason for music listening × presence of others while listening to music’ was added to the conditional model. This interaction was significant ($UC = 0.42$, $t(585) = 2.049$, $p = 0.041$). When listening to music alone, subjective stress levels were lowest when music was listened to for the reason of relaxation ($\gamma_{1|0} = -0.3852$, $t(601) = -3.7347$, $p \leq 0.001$), whereas when listening to music in the presence of others, there was no effect of reasons for music listening on subjective stress levels ($\gamma_{1|1} = 0.1029$, $t(601) = 0.5797$, $p = 0.5624$).

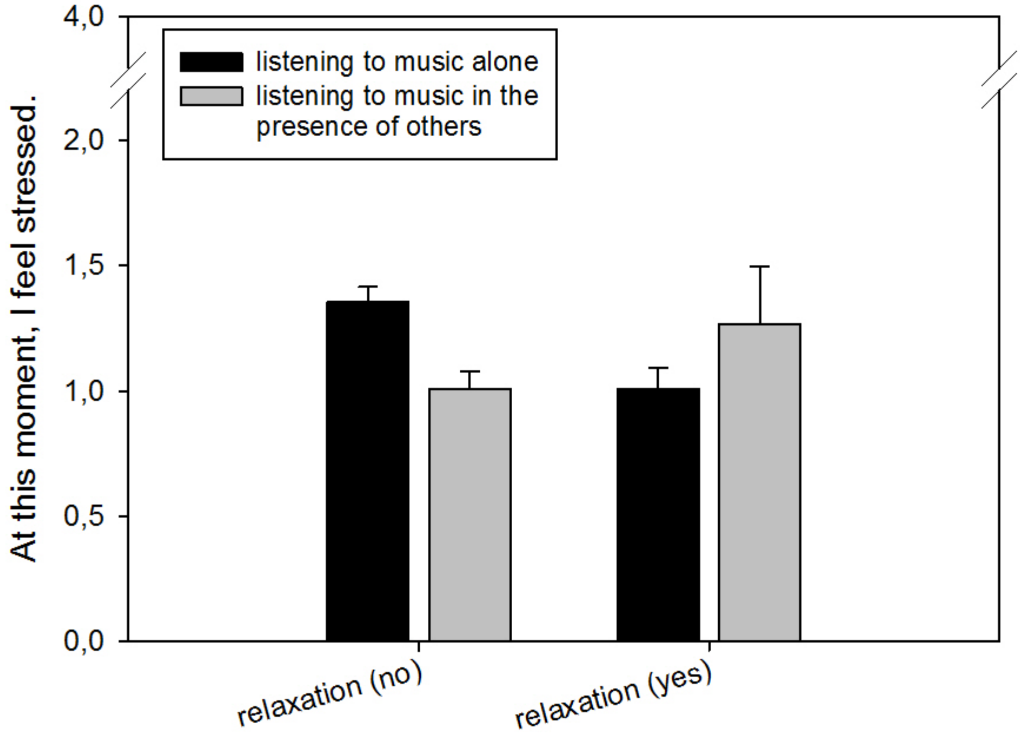

Figure 2: Mean stress level as a function of relaxation (0/1) and presence of others while listening to music (0/1). Note: error bars represent standard error of the mean

4 Discussion

This study was designed to test the hypothesis that the presence of others enhances the stress-reducing effect of music listening in daily life. Overall, music listening per se was not associated with a stress-reducing effect. However, listening to music in the presence of others was associated with decreased subjective stress levels, attenuated secretion of sCort, and higher sAA activity. These effects were not due to the mere presence of others when the assessment was triggered, as music listening in the presence of others additionally explained variance in subjective stress levels, secretion of sCort and sAA activity. Furthermore, these effects were independent of the familiarity of the people present and of the reasons for music listening. Reasons for music listening, in particular relaxation, only predicted successful stress reduction when music listening in solitude was reported.

Table 2 Hierarchical linear models predicting repeatedly assessed momentary subjective stress levels, salivary cortisol (sCort) secretion as well as salivary alpha-amylase (sAA) activity by presence of others while listening to music using restricted maximum likelihood

	subjective stress levels predicted by presence of others while listening to music		sCort secretion predicted by presence of others while listening to music		sAA activity predicted by presence of others while listening to music	
Fixed Effects	Unstandardized Coefficients	SE (df), *p*	Unstandardized Coefficients	SE (df), *p*	Unstandardized Coefficients	SE (df), *p*
Intercept Level-2	1.73	0.23 (51), *≤ 0.001*	12.19	0.16 (50), *≤ 0.001*	13.89	0.19 (50), *≤ 0.001*
Gender	0.04	0.17 (51), *0.831*	0.12	0.12 (50), *0.308*	−0.03	0.16 (50), 0.875
BMI[1]			−0.02	0.02 (50), *0.338*	0.04	0.03 (50), 0.198
Presence of others (0/1)[2]	−0.09	0.10 (582), 0.362	−0.29	0.08 (582), ≤ 0.001	0.14	0.08 (582), 0.085
Presence of others while listening to music (0/1)[3]	0.14	0.16 (582), *0.378*	−0.28	0.13 (582), *0.030*	0.32	0.13 (582), *0.011*
Interaction term[4]	−0.37	0.19 (582), *0.050*	0.14	0.15 (582), *0.342*	−0.20	0.14 (582), *0.164*
Valence (0-100)[5]	−0.00	0.00 (582), *0.060*	−0.00	0.00 (582), *0.890*	−0.00	0.00 (582), *0.424*
Arousal (0-100)[6]	0.00	0.00 (582), *0.392*	−0.00	0.00 (582), 0.487	0.00	0.00 (582), 0.043
Control over choice of music (0/1)[7]	0.04	0.10 (582), *0.665*	−0.19	0.08 (582), *0.014*	0.03	0.07 (582), 0.667
Liking for music (0-100)[8]	−0.00	0.00 (582), *0.189*	0.00	0.00 (582), *0.014*	0.00	0.00 (582), 0.214
Reason relaxation (0/1)[9]	−0.25	0.11 (582), *0.025*	−0.09	0.09 (582), *0.319*	0.07	0.09 (582), 0.399
Reason activation (0/1)[9]	−0.07	0.11 (582), *0.493*	0.29	0.08 (582), *≤ 0.001*	0.01	0.08 (582), 0.903
Reason distraction (0/1)[9]	0.15	0.12 (582), *0.223*	0.00	0.09 (582), *0.967*	0.01	0.09 (582), 0.930
Reason reducing boredom (0/1)[9]	−0.12	0.17 (582), *0.478*	−0.10	0.14 (582), *0.473*	−0.01	0.13 (582), 0.930
Random Effects	Variance Component	SD (df), *p*	Variance Component	SD (df), *p*	Variance Component	SD (df), *p*
Intercept Level-1	0.29	0.54 (51), *≤ 0.001*	0.12	0.35 (50), *≤ 0.001*	0.28	0.53 (50), *≤ 0.001*
Residual	0.73	0.85	0.46	0.68	0.43	0.66

Note. [1] BMI was only entered into analyses predicting sCort and sAA, [2] presence of others at the moment the assessment was triggered, [3] (0/1): 0 = listening to music alone, 1 = listening to music in the presence of others, [4] Interaction term ‘presence of others at the moment the assessment was triggered × presence of others while listening to music’, [5] VAS ranging from 0 (sad) to 100 (happy), [6] VAS ranging from 0 (relaxing) to 100 (energizing), [7] 0 = not self-chosen, 1 = self-chosen, [8] VAS ranging from 0 (not at all) to 100 (very much), [9] 0 = no, 1 = yes

4.1 Is the mere presence of others while listening to music stress-reducing?

Music listening in the presence of others reduced subjective stress levels as well as the secretion of sCort. This extends the idea of the stress-buffering hypothesis of social support (Cohen and Wills, 1985). Here, it was shown that even the mere presence of others while listening to music is associated with stress-reducing effects. Participants in this study were not instructed to engage in any social activity that might lead to receiving social support while listening to music, but still a stress-reducing effect was found. As Boer and Akubakar (2014) found that listening to music in the presence of peers was associated with increased feelings of social cohesion, it might be speculated that the mere presence of others while listening to music listening could lead to feelings of social cohesion without specific social support interventions. Moreover, the stress-reducing effect of listening to music in the presence of others exceeded the stress-reducing effect of the mere presence of others. This is in line with findings from Pearce et al. (2015), who compared singing to a non-singing control condition (craft, creative writing) and showed that singing has beneficial effects that are specific to music and that exceed the effect of the social group context.

Interestingly, the familiarity of the people present while listening to music did not moderate this relationship. As familiarity was an important factor identified in experimental studies on the stress-reducing effect of presence of others (Kissel, 1965), our results suggest that when listening to music with others, familiarity does not affect the stress-reducing effect of listening to music in the presence of others. It is likely that in the context of music listening with others, different aspects, such as similar music preferences, are more important than the familiarity per se. However, this finding has to be interpreted with caution, as most of the music was listened to in the presence of friends. Therefore, our findings need to be corroborated in a more heterogeneous sample of music listening episodes.

4.2 Potential mechanisms underlying the stress-reducing effect of listening to music in the presence of others

With respect to specific characteristics of social encounters that may be stress-reducing in a given situation, the literature is inconsistent. Most of the studies suggest that it is not the mere presence of others that is stress-reducing, but rather that the effects of the presence of others vary depending on familiarity (Allen et al., 1991; Kissel, 1965), sex (Kirschbaum et al., 1995), and kind of social support (Ditzen et al., 2007). In the present study, the mere presence of others while listening to music was associated with a reduction in stress.

Most interestingly, music listening in the presence of others differentially affected physiological markers of stress. Whereas music listening in the presence of others decreased HPA axis activity, it increased ANS activity. Relating these findings to the existing literature, a quite heterogeneous picture emerges: Egermann et al. (2011) found in an experimental study that music listening was more arousing (as measured by skin conductance levels) when it was listened to alone compared to in a group. Liljeström et al. (2013) found no difference in heart rate and skin conductance levels when listening to music either alone or with a close friend or partner. At first glance, these findings contradict the results of the present study. Nevertheless, it is possible to reconcile the findings. Egermann et al. (2011) and Liljeström et al. (2013) examined music listening in *experimental settings*, whereas here, we studied music listening in *daily life*. Music listening might fulfill different functions depending on whether others are present while listening to music. When listening to music alone, the music seems to be in the focus of attention, whereas when listening to music in the presence of others, music might act more as a background activity. This might explain why participants in this study reported less deliberate music listening when listening to music in the presence of others (as opposed to solitary music listening). This attributes to music rather indirect effects on health, suggesting that it may facilitate social contact and social connectedness without being the focus of attention. Such a suggestion is in line with findings on background music and well-being. For example, Ghaderi et al. (2009) found that cortisol was decreased if athletes listened to relaxing background music while exercising, mirroring our finding of lower subjective stress levels and lower sCort secretion when listening to music in the presence of others. Higher activity of sAA after listening to music in the presence of others might be explained by the arousal of the music that was listened to – even though the simultaneous observation of attenuated sCort secretion and heightened sAA activity might initially appear contradictory. Nevertheless, a recent study also found that music listening differentially affected sCort secretion and sAA activity (Linnemann et al., 2015a). The perceived arousal of the music influenced sAA activity, with energizing music increasing sAA activity and relaxing music decreasing sAA activity, respectively. Interestingly, in descriptive terms, the participants in this study rated the music they listened to in the presence of others as more arousing than the music that they listened to in solitude (see Table 1). Therefore, higher sAA activity when listening to music in the presence of others might be explained by the perceived arousal of the music.

Many mechanisms by which musical group activities fulfill social functions have been discussed (Keeler et al., 2015; Koelsch, 2013; Kreutz, 2014; Tarr et al., 2014). Tarr et al. (2014) highlight two mechanisms by which musical group activities lead to positive emotional responses and social bonding – two factors that are known to have stress-reducing properties. Interestingly, these authors distinguish the effects of musical group activities from those of passive music listening. However, passive music listening can be a group activity was well. For example, Särkämö et al. (2014) showed in dementia patients that both music making and music listening in groups have similar, positive effects on cognitive, emotional, and social functioning. Therefore, it might not be necessary to distinguish music listening from music making in this context, and mechanisms regarding musical group activities might accordingly apply for music listening in the presence of others as well. The first mechanism highlighted by Tarr et al. (2014) is called ‘self-other merging’, meaning that when engaging in musical group activities, people (involuntarily and spontaneously) synchronize with each other, which in turn leads to social bonding. Musical features such as tempo can facilitate the synchronization of movements, which can create a feeling of togetherness and bonding. Relating this to findings from stress research, feelings of social connectedness are associated with lower subjective stress levels as well as reduced HPA axis activity (Sladek and Doane, 2015).

The second mechanism by which musical group activities fulfill social functions relates to the release of endocrine hormones, especially endorphins (Tarr et al., 2014). Passive music listening has been shown to activate endorphins, especially if musical activities occur in groups. The release of endorphins is closely linked to the experience of positive emotions as well as to attenuated levels of cortisol (Taylor et al., 1983) and higher alpha-amylase activity (Ortu et al., 2015). Furthermore, there is evidence that music listening in daily life leads to more positive emotions when it occurs in the presence of others (Juslin et al., 2008). This might explain why listening to music in the presence of others decreased HPA axis activity, as positive music-induced emotions in particular have been shown to decrease HPA axis activity (Suda et al., 2008). Consequently, music-induced physiological changes and involuntary synchronization might explain why listening to music in the presence of others has stress-reducing effects in terms of subjective stress levels and HPA activity, and at the same time arousing effects in terms of ANS activity.

In line with a previous study (Linnemann et al., 2015a), music that was listened to for the reason of relaxation reduced subjective stress levels. However, this was only the case when listening to music alone, and not when listening to music in the presence of others. Different mechanisms might underlie the stress-reducing effect of listening to music depending on the social context of the listening situation. When listening to music in the presence of others, music listening seems to be a background activity, and beneficial effects occur independently of specific reasons for music listening. However, when listening to music alone, the reverse seems to be true: Only music that is deliberately listened to for the reason of relaxation is associated with attenuated stress levels. In these cases, the stress-reducing effect seems to be more closely linked to the music itself (as reasons for music listening are important) than to the presence of others while listening to music.

4.3 Limitations

Although this is a study with high ecological validity, encompassing both subjective and physiological markers of stress, certain limitations have to be discussed. First, we do not know *when* music listening took place relative to the assessment of stress markers. Especially as both sAA and sCort underlie different temporal dynamics, it cannot be ruled out that music listening occurred up to four hours before the assessment of stress. However, as we examined 53 participants for the duration of seven days with five daily assessments, we gathered a total 1855 observations with 35 observations per participant. This high number of observations per participant makes it highly unlikely that music listening (in contrast to other activities that might have occurred in-between) was not associated with stress. Furthermore, we only assessed whether participants were alone or in the presence of friends or acquaintances while listening to music, but did not ask about the quality of social interactions. Therefore, we cannot know whether the presence of others was perceived as positive or negative. Third, the proportion of music listening episodes in the presence of acquaintances was relatively small, as most of the music listening occurred in the presence of friends.

4.4 Future Directions

Future research should further characterize the nature of the stress-reducing effect of listening to music in the presence of others. By means of event-based schedules, the temporal dynamics underlying the effects of music listening on stress markers should be examined. Furthermore, future studies should assess whether participants listened to music together with others when listening to music in the presence of others. Moreover, the quality of interaction should be assessed in order to shed further light on the possible mediating role played by the social context in the stress-reducing effect of listening to music. Concerning the physiological markers assessed in this study, it would be interesting to examine the role of the neuropeptide oxytocin in future studies. Most of the studies so far examined oxytocin in the context of music making, for example in the context of group singing (e.g., Grape et al., 2003; Kreutz, 2014). However, future studies should assess oxytocin-related mechanisms in the context of music listening in the mere presence of others in order to further understand the social functions of music listening in daily life. Finally, to ultimately test hypotheses on health-beneficial effects of music listening mediated by a reduction in psychobiological stress, the assessment of immune system markers is warranted (Fancourt et al., 2016).

4.5 Conclusion

Our findings suggest that music listening has stress-reducing effects in daily life – especially when it occurs in the presence of others. This opens important avenues for music listening as a means for health promotion in daily life. Especially as stress has been related to a number of negative health outcomes, music listening in the presence of others might beneficially affect psychosocial well-being as well as (physical) health by means of stress reduction. As opposed to clinical interventions, mere music listening in daily life is easily accessible, popular, and cost-effective. Consequently, these findings should be translated into promoting music listening as health behavior in daily life. It should be recommended to engage in music listening for stress reduction purposes − either in the presence of others or deliberately for the reason of relaxation when listening to music alone.

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Paper IV

Linnemann, A., Nater, U.M., Spoerri, C., Ehlert, U, & Ditzen, B (in preparation).
Effects of music listening on couple interaction and stress in everyday life.

Please note: the authors have no conflict of interest.

Effects of music listening on couple interaction and stress in everyday life

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Abstract

Objectives: Music listening in daily life has been shown to reduce stress. Further, it has been demonstrated that this stress-reducing effect is increased if music listening takes place in a social context. Yet, to date it is unclear whether music listening has beneficial effects in the context of romantic relationships by reducing couples´ stress and by improving occurrence and quality of couple interactions.

Methods: A total of N = 40 heterosexual couples was examined by means of ecological momentary assessment. On five consecutive days, both partners were asked to complete six assessments per day on a pre-programmed iPod. These assessments covered items on their momentary stress, and on occurrence and quality of contact with their partner. Furthermore, both partners indicated whether they had been listening to music since the last assessment. After each assessment, participants provided a saliva sample for the later analysis of cortisol (sCort) and alpha-amylase (sAA).

Results: Music listening affected both the occurence as well as the quality of interaction, however only for women: they reported more contact with their partner after having listened to music. At the same time, they perceived the contact with their male partner as more negative if he had listened to music. There was no effect of music listening on subjective stress. Concerning the secretion of sCort, both women and men showed lower secretion of sCort, if the female partner had listened to music. Concerning the activity of sAA, men had higher sAA activity when their female partner had listened to music and when they themselves had listened to music. However, in case of similar music preferences, men showed lower activity of sAA when their female partner listened to music

Discussion: Music listening differentially influences couple interaction and stress. Women engage more in couple interactions after listening to music compared to men. Further, women seem to benefit in a greater extent from music listening in everyday life concerning reduction of stress. Interventions for promoting beneficial social interactions and stress reduction in couples ought to take into account that women and men differ in their use of music in everyday life.

1. Introduction

Music listening is associated with health-beneficial effects. We propose that these effects are mediated by a reduction in psychobiological stress (Thoma & Nater, 2011). Indeed, music listening in daily life has shown stress-reducing effects (Linnemann, Ditzen, Strahler, Doerr, & Nater, 2015; Linnemann, Strahler, & Nater, accepted). However, it might not be music per se, that exerts a stress-reducing effect. Rather, non-musical characteristics seem to mediate this relationship. Recently, we were able to show that the social context of the listening situation has an important impact on this stress-reducing effect as music listening in the presence of others (as compared to music listening in solitude) was associated with attenuated stress levels (Linnemann, et al., accepted).

Social integration and close social relationships in general are associated with long-term health benefits (Holt-Lunstad, Smith, & Layton, 2010). Research on mechanisms underlying the health-beneficial effects of social relationships proposes that social support buffers the detrimental effects of stress on health (Cohen & Wills, 1985). This protective effect seems to be mediated by the activity of the hypothalamic–pituitary–adrenal (HPA) axis and the autonomic nervous system (ANS). Especially being in a stable romantic relationship has been previously linked to health-beneficial effects, as married couples show long-term health benefits in comparison to unmarried individuals (Johnson, Backlund, Sorlie, & Loveless, 2000). In line with this, being married and high relationship quality in particular, seem to have a beneficial impact on stress in daily life (Holt-Lunstad, Birmingham, & Jones, 2008; Robles, Slatcher, Trombello, & McGinn, 2014). At the same time, stress is thought to be particularly harmful in couples as - assuming a dyadic approach - most often partners do not only experience their own stress, but their stress is also influenced by the stress of their partner, a phenomenon referred to as stress crossover (Neff & Karney, 2007). Therefore, stress-reducing interventions in couples are necessary. Positive couple interactions could be one of these stress-reducing interventions as frequent negative couple interactions are associated with negative health outcomes in couples (Ditzen, Hoppmann, & Klumb, 2008).

Music listening is associated with social interactions as well: it is assumed that music listening leads to social cohesion by facilitating contact, communication, coordination, and cooperation among others (Koelsch, 2013). Findings from neuroimaging studies support this notion as music listening shares neural networks that are critical to the perception and production of language (Molnar-Szakacs & Overy, 2006). Hereby, music listening can be regarded as a nonverbal form of communication (Botello & Krout, 2008). This attributes to music a promising role in the formation and maintenance of social relationships as music listening is considered as an agent of social bonding and affiliation (Clarke, DeNora, & Vuoskoski, 2015; Tarr, Launay, & Dunbar, 2014). Whereas a lot of research focused on the role of music listening for the formation of friendships and peer groups (e.g., Boer & Abubakar, 2014; Boer et al., 2011), evidence on social functions of music listening in couples remains scarce and it is unclear whether results concerning friendships and peer groups can be readily transferred to couples.

So far, most of the research on the effects of music listening in a dyadic context focused on music therapy interventions either targeting couples in which one partner is hospitalized due to some medical condition or targeting couples seeking marriage counseling. Evidence from these studies suggests that music listening has positive effects on couple interaction, providing a hint that music may act as an important facilitator for communication and connection in couples (Botello & Krout, 2008; Chavin, 2002; Hinman, 2010; Körting, Marmé, Verres, & Stammer, 2005). Furthermore, studies show that music in couples does not only improve communicative skills but also leads to relaxation (Hanser, Butterfield-Whitcomb, Kawata, & Collins, 2011; Hinman, 2010).

Consequently, there is a set of musical techniques available to help couples improving communication. These techniques vary from specialized music therapy programs for couples (Botello & Krout, 2008; Körting, et al., 2005) to individual musical interventions such as drumming, instrumental communication, or body music (Duba & Roseman, 2012). Common to all of these interventions is that they use music as a facilitator for communication. However, it has to be critically discussed that these interventions are time limited and require a therapist (Duba & Roseman, 2012). This limits the avenues music might have in couples to therapeutic settings. Therefore, the question arises as to how to use music in daily life. Specifically, it needs to be addressed if mere music listening, as opposed to music interventions, can have beneficial effects, too. An attempt to profit from music in daily life was done by Hanser et al. (2011) who developed home-based music strategies for patients with dementia and their respective caregiver. A music therapist custom-tailored a music CD and participants received instructions such as to listen to the music and to talk about music-evoked memories. This intervention led to stress reduction in the caregivers. However, this study was just exploratory in nature, as only a small number of dyads was investigated. Furthermore, none of these aforementioned studies investigated the role of music preferences for the effects of music listening in couples. However, this is particularly important, as from early as childhood onwards, similar music preferences are associated with social bonding. For example, children prefer other children with similar music preferences (Soley & Spelke, 2016) and same musical preferences are critical to social bonding in peers in adolescence (Boer, et al., 2011). However, at the same time, gender differences in musical preferences are consistently reported across studies (Colley, 2008; Rentfrow, Goldberg, & Levitin, 2011). Therefore, it remains unknown what role similar music preferences play in couples and it is unknown if social functions of music listening in couples depend on the similarity of musical preferences.

Taken together, music therapy interventions can be an effective way to improve communication and to reduce stress in couples. However, music therapy interventions are time-intensive, require professional music therapy, and have so far only been investigated in couples with a medical condition. Furthermore, most studies are qualitative or exploratory in nature and rely on self-report. Knowledge on underlying physiological mechanisms does not exist. Furthermore, there is only preliminary evidence that these interventions might be generalized to daily life. There are two research questions arising from this current evidence: First, does mere music listening in daily life (as opposed to music therapy interventions) have beneficial effects in healthy couples? That is, does music listening in daily life improve couple interaction and reduce stress? Second, which role do (similar) music preference play in the beneficial effects of music listening in couples?

Research question and hypotheses

As music interventions are used as facilitators for communication in couples, we hypothesize that music listening in couples has a positive effect on their social interactions (Hypothesis 1). More specifically, we hypothesize that partners engage more in contact after listening to music and perceive this contact with their partner to be more positive. Furthermore, as positive interactions are also associated with stress-reducing effects, we hypothesize that music listening in couples has a stress-reducing effect on both partners (Hypothesis 2) with partners experiencing less stress, if they themselves or their partner listened to music. More specifically, we hypothesize that in both partners music listening affects subjective stress, HAP axis activity, and ANS activity. In an exploratory manner, we investigated the role of music preferences for the beneficial effects of music listening in couples (Hypothesis 3).

2. Methods

This study is part of a larger project, in which the effects of oxytocin and positive couple interaction on wound healing in 80 heterosexual couples were examined. These 80 heterosexual couples were randomly assigned to one of four conditions (oxytocin and instruction for positive couple interaction, oxytocin and no instruction for positive couple interaction, placebo and instruction for positive couple interaction, placebo and no instruction for positive couple interaction).

The current analyses are based on the placebo group only (n = 40 heterosexual couples) in which half the couples received the instruction to engage in a positive couple interaction at least twice during the assessment period while the other couples did not receive such an instruction. This intervention was neither associated with music listening (UC = -0.06, $t(1933)$ = -1.215, p = 0.225) nor with the association between music listening and stress (subjective stress: UC = -0.11, $t(1542)$ = -0.682, p = 0.495; sCort: UC = -0.10, $t(1542)$ = -0.540, p = 0.589; sAA: UC = 0.30, $t(1542)$ = 1.866, p = 0.062;) nor with the association between couple interaction and stress (subjective stress: UC = -0.17, $t(1503)$ = -1.534, p = 0.125; sCort: UC = -0.12, $t(1503)$=-0.957, p = 0.339; sAA: UC = -0.10, $t(1503)$ = 0.807, p = 0.420). As results concerning the intervention will be subject of a different publication, analyses here will not consider the intervention. Furthermore, data concerning wound healing will not be considered here.

2.1 Participants

A total of n = 40 heterosexual couples was examined in the current analyses. The mean age was $\bar{x}$ = 27.72 ± 5.30 years with males ($\bar{x}$ = 28.71 ± 5.30) being older than their female partners ($\bar{x}$ = 26.74 ± 5. 18). The mean relationship duration was $\bar{x}$ = 3.72 ± 2.52 years. Only couples who lived together were included, and couples reported living together on average since $\bar{x}$ = 1.99 ± 1.67 years. According to self-reports based on the relationship quality questionnaire (Hahlweg, 1996; Hahlweg et al., 1979), participants rated relatively high values in relationship quality ($\bar{x}$ = 72.81 ± 7.43). Female partners ($\bar{x}$ = 74.05 ± 6.61) rated satisfaction higher than their male partners ($\bar{x}$ = 71.58 ± 8.07). Participants were recruited via advertisements in local newspapers, notices on local bulletin boards and advertisements in the internet. Inclusion criteria were as follows: fluent German, 21-45 years of age, being in a heterosexual exclusive relationship > one year and <15 years, sharing the same household, no children, BMI > 17 and < 30, fewer than five cigarettes per week, no current drug consumption, no daily intake of alcohol exceeding 60 g alcohol/day, no intake of medication (except hormonal contraceptives), no acute or chronic somatic, neurological or psychiatric disease, no accident with neurological secondary damages in lifetime, no allergies, no dermatological disease, no intense UV-B- exposure within the last three months prior to the investigation, and additionally for females: regular menstruation, no pregnancy, no breast-feeding. Participation in the study was voluntary and each couple received 500.00 CHF as compensation. The study was in line with the Declaration of Helsinki and approved by the Ethics Committee of the Canton of Zurich, Switzerland.

2.2 Procedure

The study was designed as an ambulatory assessment study in which couples were examined for five consecutive days in their daily life. Initially, a telephone-based interview was conducted in order to screen for the eligibility criteria. In case of eligibility, couples were invited to the University Hospital Zurich for an introductory session. During this introductory session, a pregnancy test as well as a multi-drug test were performed. Those couples assigned to the group including a positive interaction, received training for a standardized positive couple interaction. This positive couple interaction was videotaped. Those couples assigned to the group excluding this positive couple interaction did not receive this training. Instead, a ten-minute interaction between the partners was videotaped. Furthermore, partners filled out questionnaires on relationship quality, stress, and music preference, individually. Afterwards, couples were familiarized with the handling of a pre-programmed iPod®touch (iDialogPad), on which they were required to complete six assessments on each day for the following five consecutive days. Each partner received an iPod®touch. The first assessment had to be triggered by the participant directly after awakening. Subsequently, a timer activated the next assessments at 30 min, 150 min, 480 min and 720 min after awakening. The sixth assessment had to be triggered by the participants directly before going to bed. Additionally, participants were instructed to provide a saliva sample at each assessment for the later analysis of salivary cortisol (sCort) and salivary alpha-amylase (sAA). These assessments were scheduled to start the day after the introductory session.

2.3 Measures

Concerning the ambulatory assessment data, participants had to answer items six times per day. However, as the first assessment (which was triggered directly after awakening) did not contain items on music listening, this first assessment will be omitted from all subsequent analyses. An overview on the distribution of items on time of assessment can be found in table 1.

Table 1 Overview on distribution of items

Time of assessment (relative to wake-up)	Music listening behavior[1]	Couple interaction[2]	Subjective stress[3]	sCort[4] and sAA[5]
Wake-up [6]				X
+30 minutes	X			X
+150 minutes	X	X	X	X
+480 minutes	X	X	X	X
+720 minutes	X	X	X	X
Directly before going to bed [7]	X	X	X	X

Annotations: [1] music listening behavior was assessed using the item: 'Have you listened to music since the last assessment?' [2] couple interaction was assessed using items for occurrence of contact ('Did you have contact to your partner since the last assessment?') as well as quality of contact ('How did you perceive the quality of contact?') [3] subjective stress was assessed using the item: 'At this moment, I feel stressed') [4] salivary cortisol [5] salivary alpha-amylase [6] the first assessment had to be triggered directly after awakening [7] the sixth assessment had to be triggered directly before going to bed

2.3.1 Music listening behavior

Music listening behavior was assessed via self-report using a single-item approach. During each assessment (+30, +150, +480, +720, directly before going to bed), participants were asked whether they had listened to music since the last assessment. This item could either be answered 'yes' or 'no'.

In addition to this item occurring in the ambulatory assessment, both partners were asked to fill out the Music Preference Questionnaire (MPQ; Nater, Krebs, & Ehlert, 2005) online once. The MPQ comprises items on music preference in terms of preferred music genres, preferred reasons for music listening, preferred situations in which music is listened to, current and past musical activities, experience of habitual music-induced chills, as well as importance of music for one's own life. The MPQ was used in order to gain insights into the similarity of the couples' music preferences. The similarity of music preferences was determined by calculating the mean of the deviance between the preference for each item group (e.g., items on preference for music genres).

2.3.2 Couple interaction

At four assessments (+150, +480, +720, directly before going to bed), participants had to indicate whether they had contact to their partner since the last assessment (occurrence of contact). If so, they had to indicate the quality of contact on a scale ranging from 1 (negative) to 10 (positive).

In addition to these items occurring in the ambulatory assessment, both partners were asked to fill out the relationship quality questionnaire (Hahlweg, 1996; Hahlweg, et al., 1979). It allows assessing satisfaction in the partnership and comprises 30 items covering three scales: conflict behavior, tenderness, and commonalities. The questionnaire has been validated and shows good psychometric properties in terms of validity and reliability (Hinz, Stöbel-Richter, & Brähler, 2001).

2.3.3 Stress

Subjective Stress: At four assessments (+150, +480, +720, directly before going to bed), participants were asked to indicate how stressed they felt at the moment on a five point scale ranging from relaxed (1) to stressed (5). Assessing subjective stress using a single-item approach has been previously shown to be valid (Elo, Leppanen, & Jahkola, 2003).

Physiological markers of stress: Additionally, participants were asked to provide a saliva sample at each assessment for the analysis of salivary cortisol (sCort) and salivary alpha-amylase (sAA). The secretion of sCort is associated with the hypothalamus-pituitary-adrenal (HPA) axis, with increases in the secretion of sCort representing increases in HPA axis activity. The activity of sAA is associated with the activity of the autonomic nervous system (ANS), with increases in sAA activity reflecting ANS activation. Both sCort and sAA can be reliably and validly assessed in saliva (Kirschbaum & Hellhammer, 1994; Rohleder & Nater, 2009).

Using pre-labeled SaliCaps® (IBL, Hamburg, Germany), participants had to accumulate saliva for about one minute and let it passively drool into the SaliCaps®.

2.3.4 Data Analysis

Due to the nested structure of the data, analyses were performed using two-level hierarchical modeling (HLM; Raudenbush, Bryk, & Congdon, 2004). As our data is characterized by dyadic interdependence, we analyzed these data using a multilevel model for dyadic diary data that treats the three levels of distinguishable dyadic diary data (days nested within persons nested within couples) as two levels of random variation as recommended by Bolger and Laurenceau (2013). This approach allows distinguishing within-dyad from between-dyad variations. Therefore, two kinds of transformations were done prior to analysis: First, we performed an overall centering of all predictors (here: item on music listening behavior). Second, this predictor was separated into components reflecting within and between partner variation, separately for male and female partners (music listening (male), music listening (female), music listening male in rows of female and music listening of female in rows of male).

Furthermore, all analyses control for time of day due to the known diurnal variations in sCort (Kirschbaum & Hellhammer, 1989) and sAA (Nater, Rohleder, Schlotz, Ehlert, & Kirschbaum, 2007) and for body mass index (BMI) (Champaneri et al., 2013). In analyses including stress as outcome variable, we controlled for stress measures of the previous assessment. In analyses including couple interaction, we controlled for couple interaction at the previous assessment.

The analysis dataset consisted of 40 (couples) * 2 (persons) * 5 (days) * 5 (assessments per day) = 2000 potential observations concerning analyses including music listening behavior and sCort and sAA. Concerning analyses including items on couple interaction and subjective stress 40 (couples) * 2 (persons) * 5 (days) * 4 (assessments per day) = 1600 potential observations were available. However, as we controlled for stress measures or couple interaction of the previous assessment, all analyses are based on potential 1600 (sCort and sAA) or 1200 (subjective stress, couple interaction) observations.

In our first model, we specified a within couple-process of couple interaction to music listening that was hypothesized to be significant, on average, for both male and female partners. In our second model, we specified a within couple-process of stress (subjective, sCort, sAA) to music that was hypothesized to be significant, on average, for both male and female partners.

P-values of ≤ .05 were considered significant. Unstandardized coefficients (UC) are presented.

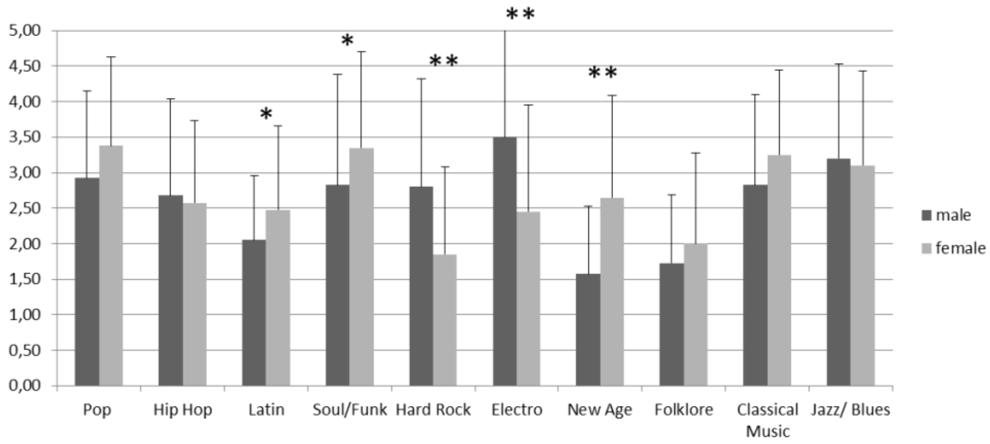
3. Results

Music listening was reported in 25.0% of time points (females: 24.4 % of time points, males: 25.6% of time points). The mean stress level experienced was $\bar{x} = 2.23 \pm 0.98$ with females reporting higher stress than males ($t(1573) = 4.662$, $p < 0.001$). Contact with the partner was reported in 44.5 % of time points (21.3% no, 34.3 % missing) and was experienced as rather positive with a mean of $\bar{x} = 7.20 \pm 1.70$.

Music listening in general was reported as important for both men and women (males $\bar{x} = 3.95 \pm 0.93$; females $\bar{x} = 4.10 \pm 0.98$). Preference for music genres differed between females and males: Females showed significantly higher preferences for latin (p = 0.042), soul/funk (p = 0.043) and new age (p < 0.001), whereas males showed higher preferences for hard rock (p < 0.001) and electro (p < 0.001). There were no differences in the habitual use of music listening for specific reasons between females and males (all p > 0.087). Also, the importance of music did not differ between females and males ($t(39) = -0.845$, $p = 0.403$).

When considering couples, it turned out that the music preference of couples was more similar with respect to genres and importance of music than in comparison to random couples generated from the data. Concerning the preference for certain music genres, the scores between the female and the male partner differed in mean for $\bar{x} = |1.17| \pm 0.40$ scores. This difference was significantly lower in comparison to random couples ($t(39) = -4.471$, $p < 0.001$). Concerning the habitual use of music for specific reasons, the mean difference was $\bar{x} = |1.30| \pm 0.42$ scores with no significant differences in comparison to random couples ($t(39) = -1.490$, $p = 0.144$). Concerning the importance of music listening, the difference concerning this item was $\bar{x} = |0.80| \pm 0.79$ scores, with a significant smaller difference in comparison to random couples ($t(39) = -2.158$, $p = 0.037$).

Figure 1 Mean preference scores for music genres separately for females and males



Note: error bars show standard deviation, * $p < 0.05$, ** $p < 0.001$

Hypothesis 1: Music listening in couples has a positive effect on couple interaction

The first hypothesis tested whether partners would engage in contact with their partner after having listened to music. The unconditional model included occurrence of contact as outcome variable, contact at previous assessment, and time since awakening at level-1 and control variables at level-2. The conditional model was specified by adding music listening (male), music listening (female), music listening male in rows of female, and music listening of female in rows of male as predictors. It turned out that women reported more contact with their partner after having listened to music ($UC = 0.08$, $t(1144) = 2.069$, $p = 0.039$). No such effect was found for males ($UC = 0.03$, $t(1144) = 0.978$, $p = 0.328$). Concerning the quality of perceived contact, it turned that women perceived their partner interactions as more negative when their partner had listened to music ($UC = -0.62$, $t(811) = -3.395$, $p < 0.001$). No such effect was found for males ($UC = -0.02$, $t(811) = -0.107$, $p = 0.915$). All results can be found in table 2.

Hypothesis 2: Music listening in couples reduces stress

In a next step, it was tested whether partners perceived less stress if they themselves listened to music and/or if their partner listened to music since the last assessment. The unconditional model included stress (subjective stress, secretion of sCort, or activity of sAA) as outcome variable, stress (subjective stress, secretion of sCort, or activity of sAA) at previous assessment, and time since awakening at level-1 and control variables at level-2. The conditional model was specified by adding music listening (male), music listening (female), music listening male in rows of female, and music listening of female in rows of male as predictors. There was no effect of music listening on subjective stress, neither for females nor for males. Concerning the secretion of sCort, women showed lower secretion of sCort, if they themselves listened to music (*UC* = -0.17, $t(1788) = -2.770$, $p = 0.006$), and men showed lower secretion of sCort, if their partner listened to music (*UC* = -0.24, $t(1788) = -3.855$, $p < 0.001$). Men showed higher sAA activity, when they themselves listened to music (UC = 0.29, t(1788) = 3.733, p < 0.001) or when their partner did (*UC* = 0.16, $t(1788) = 2.042$, $p = 0.041$). Furthermore, females showed higher sAA activity, when their partner listened to music (*UC* = 0.21, $t(1788) = 2.729$, $p = 0.006$). All results can be found in table 3.

Exploratory analysis: The role of music preferences for the association between music listening, couple interaction, and stress

As the music preference for latin, soul, new age, hard rock, and electro differed between females and males, analyses controlled for the similarity of music preference on level-2. When controlling for the similarity of music preferences, the following pattern of results emerged concerning music listening and couple interaction: There was no difference in the occurrence of contact based on the similarity of music preferences, neither for females (*UC* = 0.00, $t(1060) = 0.111$, $p = 0.912$) nor for males (*UC* = 0.00, $t(1060) = 0.071$, $p = 0.943$). Concerning stress, there was no difference in subjective stress after listening to music depending on the similarity of music preferences (females: *UC* = 0.01, $t(1122) = 0.403$, $p = 0.687$; males: *UC* = 0.00, $t(1122) = 0.094$, $p = 0.925$). However, concerning physiological markers of stress, males showed lower secretion of sCort after their female partner listened to music, however only if the music preferences were similar (*UC* = 0.27, $t(1768) = 2.449$, $p = 0.014$). Furthermore, in case of similar music preferences, men were inclined to lower activity of sAA when their female partner listened to music (*UC* = 3.49, $t(1768) = 1.922$, $p = 0.055$).

Table 2 Hierarchical linear modeling predicting repeatedly assessed contact with partner and quality of contact with by music listening using restricted maximum likelihood

	Model 1a: changes in contact with partner by number of music episode		Model 1b: changes in quality of contact by number of music episode	
Fixed Effects	Unstandardized Coefficients	SE (df), *p*	Unstandardized Coefficients	SE (df), *p*
Female	0.04	0.06 (1144), *0.510*	6.05	0.33 (811), *<0.001*
Male	-0.02	0.07 (1144), *0.737*	7.12	0.36 (811), *<0.001*
Time since awakening (female)	0.00	0.00 (1144), *<0.001*	0.00	0.00 (811), *0.001*
Time since awakening (male)	0.00	0.00 (1144), *<0.001*	0.00	0.00 (811), *0.449*
Contact with partner since last assessment (female)	0.23	0.04 (1144), *<0.001*	0.55	0.17 (811), *0.002*
Contact with partner since last assessment (male)	0.29	0.03 (1144), *<0.001*	0.09	0.18 (811), *0.626*
Music Episode (female) (0/1)[1]	0.08	0.04 (1144), *0.039*	0.15	0.19 (811), *0.414*
Music Episode (male) (0/1)[1]	0.03	0.04 (1144), *0.328*	-0.22	0.19 (811), *0.237*
Music Episode (male in rows of female) (0/1)[1]	-0.03	0.04 (1144), *0.356*	-0.62	0.18 (811), < *0.001*
Music Episode (female in rows of male) (0/1)[1]	-0.01	0.04 (1144), *0.765*	-0.02	0.19 (811), *0.915*

Note. [1] (0/1): 0 = no music listening, 1 = music listening, SE: standard error, df: degrees of freedom

Table 3 Hierarchical linear modeling predicting repeatedly assessed stress (model 2a), salivary cortisol (model 2b), and salivary alpha-amylase (model 2c) by music listening using restricted maximum likelihood

	Model 2a: Changes in subjective stress by music listening		Model 2b: Changes in salivary cortisol by music listening		Model 2c: Changes in salivary alpha-amylase by music listening	
Fixed Effects	Unstandardized Coefficients	SE (df), *p*	Unstandardized Coefficients	SE (df), *p*	Unstandardized Coefficients	SE (df), *p*
Female	1.73	0.16 (1144), *<0.001*	2.88	0.28 (1788), *<0.001*	3.41	0.30 (1788), *<0.001*
Male	1.96	0.17 (1144), *<0.001*	5.99	0.45 (1788), *<0.001*	6.70	0.42 (1788), *<0.001*
Time since awakening (female)	-0.00	0.00 (1144), *<0.001*	-0.00	0.00 (1788), *<0.001*	0.00	0.00 (1788), *0.042*
Time since awakening (male)	-0.00	0.00 (1144), *<0.001*	-0.00	0.00 (1788), *<0.001*	-0.00	0.00 (1788), *0.640*
Stress[1] at last assessment (female)	0.40	0.03 (1144), *<0.001*	0.75	0.03 (1788), *<0.001*	0.71	0.04 (1788), *<0.001*
BMI[2] (female)			0.00	0.00 (1788), *0.730*	0.00	0.00 (1788), *0.301*
Stress[1] at last assessment (male)	0.36	0.04 (1144), *<0.001*	0.50	0.05 (1788), *<0.001*	0.52	0.04 (1788), *<0.001*
BMI[2] (male)			0.00	0.00 (1788), *0.720*	-0.00	0.00 (1788), *0.921*
Music Episode (female) (0/1)[2]	-0.04	0.08 (1144), *0.652*	-0.17	0.06 (1788), *0.006*	0.03	0.08 (1788), *0.679*
Music Episode (male) (0/1)[3]	0.08	0.08 (1144), *0.342*	0.04	0.06 (1788), *0.493*	0.29	0.08 (1788), *<0.001*
Music Episode (male in rows of female)	0.12	0.08 (1144), *0.125*	0.06	0.06 (1788), *0.262*	0.21	0.08 (1788), *0.006*
Music Episode (female in rows of male)	-0.03	0.08 (1144), *0.747*	-0.24	0.06 (1788), *<0.001*	0.16	0.08 (1788), *0.041*

Note. [1] In model 2a: subjective stress, in model 2b: salivary cortisol, in model 2c: salivary alpha-amylase, [2] BMI was only controlled for in analyses concerning salivary cortisol and salivary alpha-amylase, [3](0/1): 0 = no music listening, 1 = music listening, SE: standard error, df: degrees of freedom

4 Discussion

4.1 Summary of Results

Music listening affected both the occurrence as well as the quality of couple interaction, however only for women. They reported more contact with their partner after having listened to music. Also, they perceived the contact with their partner as more negative when the male partner had listened to music. Furthermore, women perceived their partner interactions as more negative when their partner had listened to music. Concerning the stress-reducing effect of music listening, couples were differentially affected by music listening. Subjective stress levels did not vary depending on music listening in dyads. Concerning the secretion of sCort, the following pattern emerged: both women and men showed lower secretion of sCort, if the female partner had listened to music. Concerning the activity of sAA, men had higher sAA activity when they themselves had listened to music or their female partner did. Furthermore females showed higher sAA activity when the male partner had listened to music. However, in case of similar music preferences, males showed lower sAA activity when the female partner had listened to music.

Gender differences in the use of music listening as a facilitator for social interaction in dyads

Music listening in daily life was only associated with more contact in females and not in males. Thus, it might be plausible to assume, that females benefit more from social functions of music listening in that they have more contact with their partner than males do. This is an interesting finding, that is in line with Taylor et al. (2000) who state that there are gender differences in reaction to stressful situations with females engaging in a tend-and-befriend pattern that is associated with befriending (that is seeking social contact, seeking affiliation) under stress. However, it might also be possible that females and males differ in their way they seek contact to each other. For example, Ditzen, Hoppman and Klumb (2008) were able to show that females and males differed in their benefit from different kinds of social support. Whereas males benefitted from verbal support provided by their female partner, females benefitted from nonverbal support provided by their male partner. In line with this, our results can be interpreted by females using music as non-verbal form of communication for seeking contact to their partner, whereas male partners use other ways of communication to facilitate contact with their partner. This could explain why females perceived their contact to their male partner as more negative in case their male partner reported music listening. Whereas females tend to use music as a facilitator for contact, males seem to use music for different reasons. This stands in line with a finding from Boer et al. (2012) who found that young females in comparison to young males use music more often for affective functions such as emotional expression in daily life. Here, music listening in females lead to more contact with the partner, what could be considered as a form of emotional expression.

Consequently, female and males differ in their use of music in daily life as in particular emotional and social functions of music listening are more prominent in females than in males.

Gender differences in the stress-reducing effect of music listening in dyads

Gender differences in the stress-reducing effect of music listening were observed as well. Whereas both partners perceived reduced stress as measured by secretion of sCort when the female partner listened to music, both partner showed higher activity of sAA when the male partner listened to music. Thus, music listening seems to have relaxing effects in females that translate to their partner if they themselves listen to music, whereas it has activating effects in males that translates to their partner, when the male partner listened to music, respectively. This result is interesting as it supports the notion of different reasons for music listening in males and females. At the same time, this is line with findings on different strategies when being faced with a stressor: Whereas men react with a flight-or-fight-response when facing a stressor, females show this aforementioned tend-and-befriend pattern (Taylor, et al., 2000). Especially, this tend-and-befriend pattern that is characterized by engaging in actions that facilitate affiliation, could explain why females show stress-reducing effects after listening to music. Whereas females show stress-reducing effects after listening to music, males seem to get activated (what is in line with a flight-or-fight response that involves activation). This supports the notion that males and females use music for different reasons: females use it as a stress-reducing activity combined with social benefits, whereas males use music for activation and stimulation rather than social contact.

However, when music preferences were similar, males showed lower sAA activity when their female partner listened to music. This attributes to music preferences an important role in dyads. In line with empirical findings from studies examining children and adolescents, our findings support the notion that similar music preferences are important in dyads as well, as they influence the beneficial effects of music listening in dyads. As Rentfrow and Gosling (2006) identified music as a common topic to talk about when getting to know new people, it seems plausible to assume a relevant role of similar music preferences in couples as well. In fact, when analyzing dating behavior, it was shown that the majority of dating platforms ask for music preferences and people perceive music preferences as more revealing about ones personality than other aspects (Rentfrow & Gosling, 2006). This is in line with our finding that couples have similar music preferences. Furthermore, our results add to the literature that the stress-reducing effect of music listening varies depending on the similarity of music preferences.

Mechanisms underlying the beneficial effects of music listening in couples

Most interestingly, although the effects of music listening varied between the partners, a synchronization in stress-sensitive systems could be observed at the same time: When the female partner experienced a stress-reducing effect, this effect translated to the partner and vice versa. This finding is interesting, especially against the background of physiological linkage in dyads.

Mechanisms underlying the health-beneficial effect of being in a relationship are proposed. One factor alludes to physiological linkage in couples. Physiological linkage refers to patterns of covariation in physiological states among different people (Timmons, Margolin, & Saxbe, 2015). These physiological linkages can either occur in unison (in-phase changes) or in changes in opposite direction (anti-phase changes) (Reed, Randall, Post, & Butler, 2013). Up to date it is subject to debate whether physiological linkage has positive or negative effects in couples (Timmons, et al., 2015). However, a simultaneous activation of HPA axis is associated with negative outcomes in couples, whereas linkage in multiple systems is associated with beneficial outcomes (Timmons, et al., 2015). Our results show linkage in HPA axis and ANS activity that is further enhanced when similar music preferences are reported. This attributes an important role to music, as music listening in dyads might be a facilitator for physiological linkage. At the same time, processes such as physiological linkage are proposed concerning the beneficial effects of listening to music as well: Musical activities are supposed to lead to social bonding by means of synchronization (Tarr, et al., 2014). Synchronization in the context of musical activities means that people synchronize their movements to each other when being involved in musical group activities. Tarr, Launey and Dunbar (2014) argue that synchronization in musical group activities leads to social bonding mediated by the release of endorphins in the brain. Although they limit this mechanism to musical group activities, it is plausible to assume that mere music listening can lead to synchronization as well: Our results show synchronization on a psychobiological level as physiological stress-sensitive systems in dyads synchronized in reaction to mere music listening of the partner. The concept of mirror neurons supports our findings as well: Molnar-Szakacs and Overy (2006) assume that music listening can intensify social experiences due to its ability to act as a means of communication. It is supposed that this is mediated by the mirror neurons systems. Originally, mirror neurons were discovered in monkeys who showed the same pattern of neuronal activation when they either performed an action or observed it (Rizzolatti & Craighero, 2004). Nowadays, there is evidence that in humans mirror neurons work as well (Rizzolatti, 2005). This idea fits our data well, as the stress-reducing or activating effect of music listening was mirrored by the partner if the other partner listened to music. This opens interesting avenues for music listening as a means of stress-reduction in dyads, as the effects one partner perceives co-regulate the other partner as well.

Limitations

Although this is the first study to examine the effects of music listening on couple interaction and stress in healthy couples encompassing both subjective and physiological markers of stress, certain limitations have to be critically acknowledged: First of all, we only assessed whether music listening has occurred since the last assessment. Consequently, we do not know if partners listened to music together. This might be an important endeavor for future studies to investigate the effects of joint music listening on stress and couple interaction. Here, we can only draw conclusions on indirect effects of music listening on stress and couple interaction in dyads. Furthermore, we were able to show gender differences in the use of music for stress reduction and couple interaction with females benefitting more from music than males. Therefore, future studies should identify stress-reducing activities and activities that facilitate contact that might apply for males as well. Also, the sample has to be critically kept in mind. We investigated a sample of dyads with high partnership quality. It is subject to future studies to replicate these findings in couples with lower partnership quality. Especially, as conflict is a source of stress in couples (Ditzen, et al., 2008), interventions for reducing stress and improving couple interaction in high stressed couples are warranted.

Conclusion

Music listening in daily life has beneficial effects for couple interaction and the experience of stress in dyads. However, gender differences in these beneficial effects seem to apply. In particular, females seem to profit more from social functions of music listening as they have more contact with their partner after listening to music, whereas there was no such effect in men. Furthermore, there were gender differences in the stress-reducing effect of music listening in daily life. Whereas females showed lower sCort secretion after listening to music, males showed higher sAA activity after listening to music. In case of similar music preferences, males showed lower sAA activity after their partner had listened to music. Furthermore, most interestingly, synchronization of HPA axis and ANS activity in dyads were observed. Males showed lower sCort secretion if their female partner listened to music and females showed higher sAA activity if their male partner had listened to music, respectively. Therefore, despite gender differences in the use of music, music listening seems to co-regulate the experience of stress in dyads. Future research should corroborate these findings in a more heterogeneous sample.

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Paper V

Linnemann, A., Kappert, M.B., Fischer, S., Doerr, J.M., Strahler, J., Nater, U.M. (2015). The effects of music listening on pain and stress in the daily life of patients with fibromyalgia syndrome.

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The effects of music listening on pain and stress in the daily life of patients with fibromyalgia syndrome

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Music listening is associated with both pain- and stress-reducing effects. However, the effects of music listening in daily life remain understudied, and the psycho-biological mechanisms underlying the health-beneficial effect of music listening remain unknown. We examined the effects of music listening on pain and stress in daily life in a sample of women with fibromyalgia syndrome (FMS; i.e., a condition characterized by chronic pain) and investigated whether a potentially pain-reducing effect of music listening was mediated by biological stress-responsive systems. Thirty women (mean age: 50.7 ± 9.9 years) with FMS were examined using an ecological momentary assessment design. Participants rated their current pain intensity, perceived control over pain, perceived stress level, and music listening behavior five times per day for 14 consecutive days. At each assessment, participants provided a saliva sample for the later analysis of cortisol and alpha-amylase as biomarkers of stress-responsive systems. Hierarchical linear modeling revealed that music listening increased perceived control over pain, especially when the music was positive in valence and when it was listened to for the reason of 'activation' or 'relaxation'. In contrast, no effects on perceived pain intensity were observed. The effects of music listening on perceived control over pain were not mediated by biomarkers of stress-responsive systems. Music listening in daily life improved perceived control over pain in female FMS patients. Clinicians using music therapy should become aware of the potential adjuvant role of music listening in daily life, which has the potential to improve symptom control in chronic pain patients. In order to study the role of underlying biological mechanisms, it might be necessary to use more intensive engagement with music (i.e., collective singing or music-making) rather than mere music listening.

Keywords: ecological momentary assessment, fibromyalgia syndrome, music listening, pain, stress

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Introduction

Music listening has been shown to alleviate pain. Thus, it would appear to be a promising means of symptom reduction and health promotion, given that it is an activity of daily life that is popular, cost-effective and easily accessible. However, the mechanisms underlying its potential pain-reducing effect remain to be elucidated. We posit that the pain-reducing effect of music is mediated by a reduction in the activity of stress-responsive systems in the body.

Music listening is associated with reduced subjective stress levels and affects physiological markers of stress (Pelletier, 2004; Chanda and Levitin, 2013; Koelsch, 2014). Koelsch (2014) proposes a model of music-evoked emotions in which music is initially processed in the central nervous system, then further impacts endocrine, autonomic and immune activity, and leads to the experience of a broad range of emotions. A stress-reducing effect of music listening may be explained by music particularly affecting activity in the hippocampal formation, which in turn influences the activity of the hypothalamus–pituitary–adrenal (HPA) axis (Koelsch, 2014). The HPA axis constitutes one of the major stress-responsive systems in the body, and its activation leads to the secretion of the steroid hormone cortisol (Hellhammer et al., 2009). Research has linked music listening to a down-regulation of HPA axis activity, as mirrored in lower concentrations of cortisol (Chanda and Levitin, 2013). This has led to the conclusion that the health-beneficial effect of music listening is mediated by a reduction in stress (Thoma and Nater, 2011). Another stress-responsive system of high relevance is the autonomic nervous system (ANS). Music listening has also been associated with a down-regulation of ANS activity, which is reflected by both lower blood pressure and lower heart rate (Kreutz et al., 2012).

Interestingly, stress has been discussed as an etiological factor in the manifestation of chronic pain (Fitzcharles and Yunus, 2012), giving rise to the conclusion that music listening has the capacity to positively influence pain. Indeed, the term 'audio-analgesia' was coined in this context (Gardner and Licklider, 1959). Nevertheless, the exact mechanisms underlying the pain-reducing effect of music remain unclear. One open question concerns whether music listening can reduce pain *per se* (i.e., direct effect) or whether it facilitates coping with pain (i.e., indirect effect). Bernatzky et al. (2012) state that music exerts effects in the brain that directly impact on the relevant pain circuits, which in turn reduce the perception of pain intensity. However, the empirical evidence is not consistent in this regard, as there are also studies showing no music-induced reduction in perceived pain intensity (i.e., MacDonald et al., 2003). Similarly, Mitchell and MacDonald (2006) did not find a reduction in pain intensity, but did find an increase in control over pain, and thus propose that music listening is successful in reducing pain by specifically improving control over pain (Mitchell and MacDonald, 2012). While the exact mechanisms remain unclear, it has been discussed that improved control over pain may be achieved via distraction from pain or via induced relaxation (MacDonald et al., 2003; Mitchell and MacDonald, 2006; Mitchell et al., 2006).

When experiencing pain, information is forwarded from nociceptive receptors in the periphery of the body to cortical areas in the brain. Different brain mechanisms process information either serially or in parallel, with certain brain circuits being involved in the sensory-discriminative components of pain and others being involved in the affective-motivational components of pain (Treede et al., 1999). Research examining the neurobiological mechanisms underlying the pain-reducing effect of music identified the limbic system – which is involved in the affective-motivational modulation of pain – as a key structure in the brain that is affected by listening to music (Bernatzky et al., 2012). As the cortico-limbic pathways exert an inhibitory effect on pain, it is likely that music listening exerts a pain-reducing effect. At the same time, the limbic system, especially the hippocampal formation, is closely associated with the modulation of the HPA axis (Jankord and Herman, 2008). In this way, music listening is thought to exert a stress-reducing effect (Koelsch, 2014). Bernatzky et al. (2012, p. 270) state in this regard that a 'hypothalamic changeover' leads to music-induced distraction and relaxation in the context of pain. In other words, on a neurobiological level, music listening exerts effects in the central nervous system that are critical to the modulation of both pain and stress. The limbic system can be regarded as a key structure in this context, which further impacts on neuroendocrine and autonomic functioning.

However, most of the studies on music listening and pain are based on studies of acute pain in the clinical context. What remains understudied so far is the effect of music listening in chronic pain conditions (Finlay, 2014). In contrast to acute pain, which requires a pain stimulus to be present, the perception of pain in chronic pain occurs even though no current pain stimulus is present (Lee et al., 2011). This persistent experience of pain is explained by long-lasting alterations in both the central and the peripheral nervous system as nociceptive information transmission is impaired (Lee et al., 2011). Therefore, patients with chronic pain show an altered processing of sensory input, which could be linked to an effect on the limbic system (Bennett, 1999). Inhibitory effects of the thalamus on limbic structures seem to be impaired, thereby increasing the experience of pain (Bennett, 1999; Tracey and Mantyh, 2007). As chronic pain – in contrast to acute pain – is associated with these physiological alterations, it is of utmost importance to examine whether music listening can affect pain in chronic pain conditions as well.

Fibromyalgia syndrome (FMS) is a medically unexplained condition mainly characterized by chronic widespread pain impacting heavily on patients' quality of life (Woltman et al., 2012). Stress seems to play a major role in the manifestation of pain symptoms in FMS patients: it was demonstrated that patients with FMS show alterations in HPA axis (Tak et al., 2011) as well as in ANS functioning (Martinez-Lavin, 2002). We previously investigated the role of both HPA axis and ANS in the relationship between stress and pain in daily life (Fischer et al., in revision). Hereby, we have shown that stress exacerbates pain in FMS patients, with HPA axis activity (but not ANS activity) being associated with pain. As music listening has been shown to reduce stress and stress system activity, the question arises whether music listening can also have a positive impact on pain in FMS patients. The still limited number of studies point toward a pain-reducing effect of music listening in these patients (Onieva-Zafra et al., 2013; Garza-Villarreal et al., 2014). In their experimental study, Garza-Villarreal et al. (2014) found pain-reducing effects, which they hypothesized to be due to cognitive and emotional processes, as music listening might have helped to distract from the pain and lead to a state of relaxation. However, the study was set in a highly artificial laboratory context, thus limiting the generalizability of its results. Onieva-Zafra et al. (2013) conducted an intervention study set in daily life, in which FMS patients were instructed to listen to pre-recorded music CDs almost daily for 14 consecutive days. Although music listening was associated with alleviated pain intensity levels, the underlying mechanisms remain unclear, as no biological markers were assessed in this study.

Taken together, the currently available literature suggests that music listening has pain- and stress-reducing effects. The underlying mechanisms, however, remain to be elucidated. Since most of the previous studies were set in experimental contexts examining acute pain, an investigation of the psycho-biological effects of music listening on chronic pain in daily life is warranted.

Research Question

Our overarching research question is whether patients with FMS benefit from mere music listening in daily life, and what the mechanisms underpinning the potential health-beneficial effect of music listening are. Based on the evidence summarized above, we hypothesized that music listening reduces pain intensity and increases control over pain (Hypotheses 1 and 2), that music listening has a stress-reducing effect both on subjective stress levels and markers of HPA and ANS activity (Hypothesis 3), and that these biomarkers mediate the pain-reducing effect (Hypothesis 4).

Materials and Methods

Participants

A total of 30 women meeting the Fibromyalgia Research Criteria (Wolfe et al., 2011; mean age = 50.7 ± 9.9 years, range: 27–64 years) were recruited via specialized clinics and various advertising outlets from the general population (i.e., newspapers, self-help groups, internet) as part of a bigger study on everyday life stress in patients with functional somatic symptoms. The eligibility criteria were as follows: diagnosis of fibromyalgia according to the Fibromyalgia Research Criteria, female sex (due to the majority of FMS patients being female, Wolfe et al., 1995), German as native language, age between 18 and 65 years, body mass index (BMI) in the range of 18–30, regular menstrual cycle or being post-menopausal, no acute or chronic unmedicated conditions influencing biological stress markers, no current pregnancy or breast-feeding, no lifetime psychotic or bipolar disorder, no eating disorder within the past five years, no substance abuse within the past two years, and no current episode of major depression. As compensation, participants received 80 Euro. The participants were informed about the aims of the study and gave written informed consent. The study was approved by the Ethics Committee of the Department of Psychology at the University of Marburg, Germany.

Procedure

The study was designed as an ecological momentary assessment study (Shiffman et al., 2008). Participants were examined on 14 consecutive days. Initially, potential participants underwent a telephone-based interview in order to check the eligibility criteria. If they fulfilled the criteria, they received a detailed study description by post. Subsequently, participants were invited to the laboratory for an introductory session. For the duration of the study, patients received an iPod® touch (Apple, Cupertino, CA, USA), on which they were required to complete six daily assessments on each day by means of the software iDialogPad (G. Mutz, University of Cologne, Germany). The participants were instructed to switch on the iPod® upon waking up the following morning, not to turn it off from then on, and to recharge it every night. The assessment period began on the day following the introductory session. Each day, participants were asked to trigger the first assessment themselves directly after awakening. An activated timer prompted participants to complete a second set of questions 30 min afterwards (to determine the cortisol awakening response, which was not used in the current analyses). Further fixed assessments followed at 11.00, 14.00, 18.00, and 21.00 h. Participants were instructed to provide a saliva sample after each assessment for the later analysis of salivary cortisol and salivary alpha-amylase, for which they were provided with pre-labeled tubes. After completing the 14 days of assessment, the participants returned to the laboratory to hand over the saliva samples and iPod®. On this occasion, they also completed online-based questionnaires. Additionally, a post-monitoring interview was conducted, checking for problems in handling the iPod® or problems with the collection of saliva samples and asking for any unusual events during the measurement period.

Measures

Ecological Momentary Assessment Items

At all assessments, except for directly after awakening, participants had to complete items regarding their music listening behavior, their momentary pain experience, and their momentary stress level.

Music listening behavior

Participants were asked whether they had deliberately listened to music since the last assessment, which was defined as actively deciding to listen to music (i.e., by turning on the radio or a music listening device). If they reported deliberate music listening, they were then required to answer further items concerning their listening to music. They were asked to rate the perceived valence on a visual analog scale (VAS) ranging from 0 (‘sad’) to 100 (‘happy’) and the perceived arousal on a VAS ranging from 0 (‘relaxing’) to 100 (‘energizing’). In the context of music, pain, and stress, the dimensions of valence and arousal are of special relevance. While the kind of music that is effective in reducing pain is still subject to debate, there is accumulating evidence that music which is positive in valence is especially effective, independent of its arousal (Roy et al., 2008). However, in the context of stress, the reverse pattern seems to be true, with music which is low in arousal being especially effective in reducing stress (Kreutz et al., 2012; Chanda and Levitin, 2013). Based on the occurrence of deliberate music listening, time points were classified as ‘music episodes’ if deliberate music listening was reported.

Subsequently, participants were asked to indicate the reasons why they had listened to music by choosing from among the following options: ‘relaxation,’ ‘activation,’ ‘distraction,’ and 'reducing boredom.' These have been stated as the most common reasons for listening to music in previous studies (Juslin et al., 2008; Linnemann et al., 2015b). Further, in the context of pain, it has been long discussed whether music listening is effective in reducing pain by distracting from pain and/or by inducing relaxation (Mitchell and MacDonald, 2012). This therefore highlights the importance of investigating the link between reasons for music listening and potential pain- and stress-reducing effects.

Pain

Perceived pain intensity (Myles et al., 1999) and control over pain (Haythornthwaite et al., 1998) were measured as indicators for the experience of pain. Perceived pain intensity was measured using a VAS ranging from 0 ('At the moment, I am in no pain') to 100 ('At the moment, I am in the most intense pain possible'). Perceived control over pain was measured using the item 'I had the feeling that I was in control of the pain,' which was rated on a 6-point Likert scale ranging from 0 to 5, with low values indicating low control over pain and high values indicating high control.

Stress

Subjective stress

Subjective stress was measured using the item 'At the moment, I feel stressed,' which was rated on a 5-point Likert scale ranging from 0 ('not at all) to 4 ('very much'). In order to keep the number of items asked to a minimum, we decided to use a single- item measure for stress, which proved to have sufficient psychometric qualities (Elo et al., 2003).

Physiological stress

After each assessment, participants were asked to collect a saliva sample for the later analysis of salivary cortisol (sCort) and salivary alpha-amylase (sAA) which we measured as biomarkers of stress. High cortisol levels generally indicate high levels of stress (Hellhammer et al., 2009). The secretion of cortisol follows a marked diurnal rhythm, with a rise in the morning and a subsequent decrease of cortisol towards the evening. sAA is an enzyme which is secreted from the salivary glands in the oral cavity. As its secretion is regulated by the ANS, sAA is also regarded as an indirect indicator of autonomic activation (Nater and Rohleder, 2009). Like cortisol, alpha-amylase follows a distinct diurnal pattern, with a decrease within 60 min after awakening and a steady increase of activity during the course of the day. Both sCort and sAA can be considered as valid physiological markers of stress system activity (Nater et al., 2013).

Measures of sCort and sAA were obtained from the unstimulated whole saliva samples collected during the 14-day measurement period. The participants were instructed to collect the samples as follows: first, they should rinse their mouth with water and then swallow all remaining saliva before collecting saliva for 2 min, which they should then transfer into SaliCap® tubes via a straw. They were also asked to refrain from eating, smoking, brushing their teeth, or drinking anything but water for 1 h prior to sample collection. Participants were asked to store samples in a freezer or a fridge as soon as possible at home. Upon returning to the laboratory, the samples were stored at −20°C at the Biochemical Laboratory of the Department of Psychology, University of Marburg, until analysis. sCort levels were measured using a commercially available enzyme-linked immunoassay (IBL, Hamburg, Germany). sAA activity was measured using a kinetic colorimetric test and reagents obtained from Roche (Fa. Roche Diagnostics, Mannheim, Germany). Inter- and intra-assay variance for both sCort and sAA was below 10%.

Paper–Pencil Questionnaires

During the introductory session, participants were asked to complete a questionnaire on their socio-demographic background. Furthermore, after having completed the study protocol, participants completed the music preference questionnaire once online (MPQ; Nater et al., 2005). The MPQ provides insight into participants' habitual music listening behavior and is based on their subjective experience of their music listening behavior. The first item covers the preference for the most common music genres (i.e., 'pop,' 'rock,' 'classical music') by asking participants to indicate which music genre they prefer, using a scale ranging from 1 ('not at all') to 5 ('very much'). Subsequent items evaluate common reasons for music listening (i.e., 'relaxation,' 'activation,' 'distraction), with participants being asked to indicate how frequently they listen to music for the respective reasons on a scale from 1 ('never') to 5 ('very often'). Further items cover participants' music-making experience (i.e., information about playing an instrument or singing in a choir). Finally, the personal significance of music for participants is stated on a scale ranging from 1 ('not important') to 5 ('very important').

Statistical Analyses

In order to account for the nested structure of the data, analyses were performed using two-level hierarchical linear modeling (HLM; Raudenbush et al., 2004). Perceived pain intensity, perceived control over pain, subjective stress, sCort, sAA, and items on music listening such as music listening (yes/no), valence, arousal, and reasons for music listening were considered as level-1 variables. Furthermore, at the momentary level (level-1), the time of day was entered into analyses concerning the relationship between biological parameters and music listening due to the known diurnal patterns of both sCort and sAA. However, as only time points at which music listening was reported were entered into analyses concerning valence/arousal and reasons for music listening (thus reducing the number of level-1 observations), we did not include time of day as predictor in these analyses. Exploratory analyses revealed that entering time of day as predictor did not alter the results. At the individual level (level-2), the intercept (β_0) was modeled as a function of number of music episodes (γ_{01}) and a residual component (u_0). In analyses concerning biological parameters, both age and BMI were entered additionally at the individual level (level-2) due to their known associations with HPA axis and ANS regulation.

The total number of music episodes varied between 0 and 53 per participant per measurement period, with participants listening to music once per day on average ($\overline{X} = 13.80 \pm 13.34$). Therefore, we controlled for the total number of music episodes on level-2, although this only turned out to be a significant predictor in one model (Model 2a). A total of 70 measurements were available per participant (five time points per day for 14 consecutive days), making a total of 2100 possible observations. As HLM uses a listwise deletion procedure in the case of missing values, the degrees of freedom (df) vary between the tested models. In models concerning subjective reports of stress, a total of 1883 observations were entered into the analyses. With regard to neuroendocrine and autonomic markers of stress, a total of 1773 observations were entered into the analyses. As music listening occurred in 21.2% of daily assessments, the number of degrees of freedom was further reduced to 412 when subjective stress reports were considered as the outcome and 379 when biological markers of stress were considered as the outcome, respectively. As neither sCort nor sAA was normally distributed, we natural log-transformed both sCort and sAA [ln (x) + 10]. Two participants had not listened to music at all during the 14-day period of assessment, and were therefore not entered into analyses in which valence/arousal as well as reasons for music listening were examined.

Hypothesis testing was performed in accordance with Woltman et al. (2012). Therefore, both unconditional and conditional models were specified. The comparison between these models was undertaken by means of χ^2- statistics, comparing the reduction in deviance as a measure of model fit. As an indicator of explained variance, pseudo-R^2 is reported, calculated in accordance with the formula [(σ^2(unconditional growth model) − σ^2(subsequent model))/σ^2(unconditional growth model)] (Singer and Willett, 2003). Mediation analyses were performed using the stepwise procedure as recommended by Kenny et al. (2003), Korchmaros and Kenny (unpublished).

P-values of $\leq$0.05 were considered significant. For all analyses, unstandardized coefficients (UC) are reported.

Results

Participants reported having suffered from FMS for a mean of 120 ± 86 months. The mean BMI was 25.24 ± 2.90. Four participants had conditions which potentially influenced sCort or sAA: one had a BMI of 31.2, one suffered from Hashimoto's thyroiditis, and two suffered from inflammatory respiratory diseases. As there is no reason to assume that these conditions affect subjective data, these participants were included in all analyses regarding subjective data. For analyses in which biological markers were included, we initially excluded these four participants, although as their exclusion did not alter the pattern of results, we decided to include these patients in all analyses for the sake of consistency.

Data from the MPQ ($n = 29$) on participants' habitual music listening behavior revealed that patients listened to music on average for 2.0 ± 2.2 h per day. The reasons most commonly stated for listening to music were: 'activation' ($\overline{X} = 3.62$), 'relaxation' ($\overline{X} = 3.52$), and 'distraction' ($\overline{X} = 3.31$). Concerning the importance of music for their lives, on a scale ranging from 1 ('not at all important') to 5 ('very important'), patients reported a moderate level of importance ($\overline{X} = 3.38 \pm 1.37$). A total of seven participants (=24.1%) reported that they were currently actively making music. Half of the participants ($n = 15$) stated that they had actively made music in the past.

With regard to the ecological momentary assessment data, music listening was reported in 21.2% of daily assessments. The music that was listened to was rated as rather positive in valance ($\overline{X} = 72.9 \pm 14.1$) and high in arousal ($\overline{X} = 61.42 \pm 22.7$). The reasons most commonly stated for music listening were: 'relaxation' (48.8%), 'distraction' (34.5%), 'activation' (25.8%), and 'reducing boredom' (12.3%).

The overall mean pain intensity, rated on a scale ranging from 0 to 100, was $\overline{X} = 47.5 \pm 25.0$. On a scale from 0 to 5, patients rated a moderate level of perceived control over pain $\overline{X} = 2.82 \pm 1.1$. Perceived stress was rated with a mean of $\overline{X} = 1.5 \pm 1.0$ on a scale from 0 to 4.

Does Music Listening in Daily Life Reduce Perceived Pain Intensity (Hypothesis 1)?

We first examined whether music listening was associated with reduced levels of perceived pain intensity (Model 1a). The unconditional model included only perceived pain intensity as dependent variable at level-1 and number of music episodes at level-2, and no music listening. We then specified the following conditional model: perceived pain intensity levels were modeled as a function of music listening (yes/no; β_{1j}) and a residual component (r_{ij}). At the individual level (level-2), both the intercept (β_0) and the slope (β_1) were modeled as a function of number of music episodes (γ_{01}, γ_{11}) and a residual component (u_0). However, there were no associations between music listening and perceived pain intensity [$UC = 1.64$, $t(1918) = 1.001$, $p = 0.317$]. As music listening *per se* did not affect pain intensity, we tested whether music characteristics, i.e., perceived valence and arousal of the selected music, influenced perceived pain intensity (Model 1b). We specified the following conditional model: perceived pain intensity levels were modeled as a function of valence (0–100) (β_{1j}), arousal (0–100) (β_{2j}), and a residual component (r_{ij}). At the individual level (level-2), the intercept (β_0) was modeled as a function of number of music episodes (γ_{01}) and a residual component (u_0). Neither valence [$UC = -0.03$, $t(384) = -0.328$, $p = 0.743$] nor arousal [$UC = -0.09$, $t(384) = -1.221$, $p = 0.223$] was associated with any changes in perceived pain intensity. Concerning the reasons for music listening (Model 1c, **Table 1**), 'activation' was the only reason associated with a reduction in perceived pain intensity. The reduction in deviance (from the model including 'relaxation,' 'distraction,' and 'reducing boredom' as predictors to the model additionally including 'activation' as predictor) was marginally significant ($\chi^2 = 12.11$; df = 6; $p = 0.059$), with 'activation' explaining 1.86% of the variance in perceived pain intensity.

Does Music Listening in Daily Life Increase Control Over Pain (Hypothesis 2)?

Next, we examined whether music listening was associated with increased levels of perceived control over pain. The unconditional model included only perceived control over pain as dependent variable at level-1 and number of music episodes at level-2, and no music listening. The conditional model (Model 2a) examined whether the level of perceived control over pain varied as a function of music listening (yes/no; β_{1j}) and a residual component (r_{ij}) at level-1. At the individual level (level-2), both the intercept (β_0) and the slope (β_1) were modeled as function of number of music episodes (γ_{01}, γ_{11}), and a residual component (u_0). In line with our expectations, music listening was associated with higher levels of perceived control over pain [$UC = 0.30$, $t(1458) = 3.548$, $p < 0.001$]. Furthermore, the number of music episodes influenced the association between perceived control over pain and music listening [$UC = 0.01$, $t(1458) = 2.047$, $p = 0.041$], with those reporting more music episodes experiencing more control over pain. The reduction in deviance was significant ($\chi^2 = 14.59$; df = 4; $p = 0.006$), with 0.83% of the variance in control over pain being explained by our predictors.

We then examined whether perceived control over pain varied as a function of the perceived valence and arousal of the selected music (Model 2b). Therefore, we specified a conditional model with valence (0–100) and arousal (0–100) being included as predictors at level-1, and at level-2 the intercept was modeled as a function of number of music episodes. Valence [$UC = 0.01$, $t(292) = 2.719$, $p = 0.007$], but not arousal [$UC = 0.00$, $t(292) = 0.285$, $p = 0.776$], was associated with higher levels of perceived control over pain. The reduction in deviance was significant ($\chi^2 = 10.78$, df = 4, $p = 0.029$), with 2.35% of the variance in perceived control over pain being explained. Next, we examined whether reasons for music listening were associated with the level of perceived control over pain. Therefore, we specified a conditional model in which the reasons for music listening [‘relaxation’ (yes/no), ‘activation’ (yes/no), ‘distraction’ (yes/no), and ‘reducing boredom’ (yes/no)] were included as predictors at level-1 (Model 2c, **Table 1**). We found that ‘relaxation’ and ‘activation’ were associated with an increase in perceived control over pain, with 3.79% of the variance in control over pain being explained by reasons for music listening ($\chi^2 = 17.08$, df = 6, $p = 0.009$).

Does Music Listening in Daily Life Reduce Stress in Patients with FMS (Hypothesis 3)?

Subjective Stress

We examined whether music listening was associated with reduced levels of subjective stress (Model 3a). The unconditional model included only subjective stress as dependent variable at level-1 and number of music episodes and a residual component at level-2, and no music listening. Concerning the conditional model (Model 3a) subjective stress levels were modeled as a function of music listening (yes/no; β_{1j}) and a residual component (r_{ij}). At the individual level (level-2), both the intercept (β_0) and the slope (β_1) were modeled as a function of number of music episodes (γ_{01}, γ_{11}) and a residual component (u_0). There was no association between music listening and subjective stress [$UC = -0.12$, $t(1918) = -1.204$, $p = 0.229$]. Subsequently, we examined whether valence or arousal were associated with subjective stress, adjusting the conditional model accordingly with valence and arousal at level-1, and only the intercept being modeled as a function of number of music episodes at level-2 (Model 3b). However, neither valence [$UC = -0.00$, $t(384) = -0.855$, $p = 0.393$] nor arousal [$UC = 0.00$, $t(384) = 0.752$, $p = 0.453$] was associated with subjective stress. Concerning the reasons for music listening (Model 3c, **Table 1**), ‘activation’ was the only reason for music listening which was associated with lower subjective stress levels. The reduction in deviance (calculated as the reduction in deviance from the unconditional model to the conditional model) was significant ($\chi^2 = 12.75$, $df = 6$, $p = 0.047$), with 2.42% of the variance being explained by reasons for music listening.

TABLE 1 | Hierarchical linear models predicting repeatedly measured perceived pain intensity (70 measures; Model 1c), repeatedly measured perceived control over pain (70 measures; Model 2c) as well as repeatedly measured subjective stress (70 measures; Model 3c) by reasons for music listening using full maximum likelihood.

	Model 1c: changes in pain intensity by reason for music listening		Model 2c: changes in control over pain by reason for music listening		Model 3c: changes in subjective stress by reason for music listening	
Fixed effects	**UC[1]**	**SE[2] (df), *p***	**UC[1]**	**SE (df), *p***	**UC[1]**	**SE (df), *p***
Intercept level-2	53.76	6.68 (26), *≤0.001*	2.82	0.29 (25), *≤0.001*	1.49	0.28 (26), *≤0.001*
Number of music episodes[4]	−0.10	0.31 (26), *0.752*	0.01	0.01 (25), *0.645*	0.01	0.01 (26), *0.498*
Relaxation[5] (0/1)	−1.07	2.66 (382), *0.688*	0.29	0.08 (290), *≤0.001*	−0.29	0.17 (382), *0.085*
Activation[5] (0/1)	−5.49	2.63 (382), *0.038*	0.29	0.08 (290), *≤0.001*	−0.29	0.14 (382), *0.037*
Distraction[5] (0/1)	−0.66	2.39 (382), *0.781*	−0.14	0.07 (290), *0.065*	0.15	0.12 (382), *0.209*
Reducing boredom[5] (0/1)	−4.23	3.24 (382), *0.192*	0.16	0.24 (290), *0.503*	−0.10	0.30 (382), *0.735*
Random effects	**VC[6]**	**SD[3] (df), *p***	**VC[6]**	**SD (df), *p***	**VC[6]**	**SD (df), *p***
Intercept level-1	467.48	21.64 (26), *≤0.001*	0.73	0.85 (25), *≤0.001*	0.37	0.61 (26), *≤0.001*
Residual	203.87	14.28	0.37	0.61	0.63	0.80

[1]UC, Unstandardized Coefficients. [2]SE, Standard Error. [3]SD, Standard Deviation. [4]Number of music episodes: total number of music episodes per participant per measurement period (0–53). [5](0/1): 0 = no, 1 = yes. [6]VC, Variance Component.

Physiological Parameters of Stress

Music listening was not associated either with sCort [$UC = -0.06$, $t(1816) = -0.694$, $p = 0.488$] or with sAA [$UC = -0.01$, $t(1807) = -0.078$, $p = 0.938$]. Furthermore, valence and arousal ratings did not affect sCort concentrations [valence: $UC = 0.00$, $t(352) = 1.034$, $p = 0.302$; arousal: $UC = 0.00$, $t(352) = -1.244$, $p = 0.214$] or sAA activity [valence: $UC = 0.00$, $t(352) = 0.927$, $p = 0.354$; arousal: $UC = 0.00$, $t(352) = 0.743$, $p = 0.458$]. None of the reasons for music listening was associated with sCort secretion [$UC < 0.11$, $t(350) < 1.092$, $p > 0.276$], as was the case with sAA activity [$UC < -0.11$, $t(350) < -0.789$, $p > 0.431$].

Is the Pain-Reducing Effect of Music Listening Mediated by the Biological Stress-Responsive Systems (Hypothesis 4)?

As our analyses above identified relations among control over pain, the reason of 'relaxation,' and the reason of 'activation,' we only tested whether the increase in perceived control over pain when music was listened to for the reason of 'relaxation' and 'activation' was mediated by the biological stress-responsive systems. However, as none of the reasons for music listening was associated either with sAA or with sCort [see Does Music Listening in Daily Life Reduce Stress in Patients with FMS (Hypothesis 3)?], conditions for mediation analyses were not met and we therefore refrained from performing mediation analyses.

Discussion

We found a beneficial effect of listening to music on how FMS patients coped with pain in daily life: whereas the perceived pain intensity was not affected by listening to music, perceived control over pain was significantly increased after having listened to music. This effect was especially profound in participants who listened to music more often, with an increase in the number of music episodes being associated with an increase in the pain-reducing effect of music listening. The perceived valence and the reasons for music listening ('relaxation' and 'activation' emerged as the most important factors) seem to be especially relevant, as they predicted increases in control over pain. We did not find a specific stress-reducing effect of music in FMS patients. The reason of 'activation' again predicted successful reduction in subjective stress, but the biological stress-responsive systems were not affected by music listening in daily life in these patients. Thus, the pain-reducing effect of music listening did not prove to be mediated by a reduction in levels of stress biomarkers.

Mirroring the heterogeneity in findings on the effects of music listening on pain intensity (Mitchell and MacDonald, 2012), we were not able to find an effect of music listening on pain intensity in daily life. It is assumed that music listening exerts its effects in the central nervous system, which then triggers emotional and cognitive processes as well as alterations in the peripheral nervous system (Koelsch, 2014). Evidence supports the notion that music-induced analgesia is produced by the central nervous system, but does not translate into the peripheral nervous system, i.e., by affecting nociceptive receptors (Garza-Villarreal et al., 2014). Especially as FMS is characterized by a sensitization to pain combined with dysregulated pain-inhibitory pathways, our results support the notion that mere music listening in daily life does not yield improvements in pain intensity in patients with FMS. Although Onieva-Zafra et al. (2013) did find an effect of music listening on pain intensity in patients with FMS, these patients were instructed to listen to music at least once a day for 30 min in the context of a trial. In our study, participants did not receive any instructions regarding their music listening. Our sample listened to music once a day on average while going on with their daily lives; half of our participants listened to music more than once a day and the other half listened to music less than once a day. The effects of an intervention in which patients are guided to listen to music on a daily basis might therefore be beyond the effects of our study, as we did not manipulate the music listening behavior of our participants, but rather studied the short-term effects of music listening as it happens in daily life. More profound effects of music listening might be observable if people were specifically instructed to engage with music on a regular basis.

Pothoulaki et al. (2012) argue that music interventions cannot affect physiological processes in chronic diseases but can yield improvements in quality of life, with increasing perceived control as one mechanism through which music listening has health-beneficial outcomes. Turner et al. (2007) support this notion, as they showed that improvements in pain coping as achieved by cognitive-behavioral therapy (CBT) are mostly mediated by increases in control over pain. We were able to show that control over pain was improved after listening to music – especially for those who reported listening to music more regularly. It is assumed that characteristics both of the music and of the listener contribute to the pain-reducing effect of music listening (Mitchell and MacDonald, 2012; Pothoulaki et al., 2012). Here, we replicated the finding that music rated as high in valence was effective in reducing pain (Roy et al., 2008). However, the arousal of the music did not play a major role, in contrast to evidence from previous studies in which music low in arousal was used as a stimulus (Garza-Villarreal et al., 2014; Picard et al., 2014). To the best of our knowledge, we were the first to show that reasons for music listening seem to be especially relevant to the health-beneficial effect of music listening (Linnemann et al., 2015a). In the current study, especially 'activation' and 'relaxation' predicted an increase in control over pain, suggesting that music listening might lead to successful pain management. At first glance, these two reasons for music listening seem to be contradictory, but these findings can be reconciled: In the management of pain, both relaxation and activation are well-known strategies that have the potential to reduce pain. With regard to activation, CBT therapists instruct patients to reduce avoidance behavior as this is thought to maintain the persistence of chronic pain (Philips, 1987; McCracken and Samuel, 2007). On the other hand, relaxation techniques were shown to be associated with improved coping with pain (Turner et al., 2007). Therefore, both activation and relaxation can lead to improvements in pain management.

Interestingly enough, the reason of 'distraction' was not found to decrease pain in our study. This is striking, especially as distraction is thought to be a major contributor to music-induced analgesia (Mitchell and MacDonald, 2012; Pothoulaki et al., 2012). Although we cannot rule out that patients actually perceived distraction while pursuing activation and relaxation when listening to music, distraction in daily life seems to be inefficient for coping with pain in chronic pain patients.

Our model proposes that the health-beneficial effect of listening to music is mediated by a reduction in stress (Thoma and Nater, 2011). There is evidence in the literature that the stress- and pain-reducing effects of listening to music are inter-related (Garza-Villarreal et al., 2014). Some experimental studies have shown that music listening affects both pain and stress (Good and Ahn, 2008; Bauer et al., 2011). However, others have demonstrated that music listening exclusively affects pain management and does not affect stress (Good et al., 2013). Nevertheless, these studies were predominantly conducted in experimental settings, examining acute pain either in healthy controls or in patients undergoing surgery. Furthermore, patients had to listen to music that was mostly chosen by the experimenter. This procedure is questionable, as it is known from the literature that self-selected music exerts the greatest stress-reducing effects (Chanda and Levitin, 2013). Therefore, we chose not to influence the music listening behavior of our participants but examined the effects of mere music listening in daily life. In our study, the pain-reducing effect of listening to music was not mediated by biological stress-responsive systems. This might be due to the already distorted ANS and HPA axis functioning in patients with FMS (Martinez-Lavin, 2002; Tak et al., 2011). Our results suggest that mere music listening may not be capable of impacting these chronic alterations in HPA and ANS functioning. Nevertheless, it remains open to further investigation whether, by means of event-based sampling methods, effects of music listening on acute stressors might be found. Furthermore, it might be possible that a more intense engagement with music (i.e., more music listening, active music-making) might be necessary in order to affect these systems in the body. In this context, music intervention studies set in daily life should examine whether the disease-induced alterations in HPA and ANS functioning can be positively affected.

Although this is the first study to examine the effects of music listening on pain and stress in patients with FMS in an everyday life setting, combining both psychological and biological outcomes, this study is not without limitations. First, the timing of the assessment relative to the music listening does not allow us to draw any conclusions about immediate effects of music listening on pain and stress. As there were, in part, up to 4 h between music listening and the assessments, we cannot rule out that music listening had acute effects on subjective pain and stress reports which were not sufficiently persistent to be captured by the later assessment. Second, we only asked about deliberate music listening. Thus, we cannot rule out that participants were exposed to background music during episodes that we coded as no-music episodes. Future studies are necessary to examine the effects of background music on health-related outcomes. Third, our sample size was moderate, although we did use a repeated measures design, which leads to a high number of observations per participant. Fourth, our hypotheses are based on within-person observations. A comparison group (i.e., participants with acute pain and/or healthy participants) would allow the testing of between-subject hypotheses that examine the potentially different mechanisms underlying the pain-reducing effects of music listening between a population with chronic pain versus a population with acute pain. Finally, as we only assessed women, our results do not allow generalizations to male FMS patients. This should be a focus of future research.

Conclusion

Fibromyalgia syndrome is a complex and in part poorly understood chronic pain disorder. An optimal management of pain is not yet available, although a multimodal approach including music interventions has been suggested (Onieva-Zafra et al., 2013; Picard et al., 2014). We were able to show that mere music listening in daily life has beneficial effects on control over pain. It seems to be relevant why one listens to music, as in our study, listening to music for the reason of 'activation' or 'relaxation' predicted successful pain coping. We did not find this pain-reducing effect to be mediated by stress-responsive systems. Future studies need to examine acute effects of music listening on pain and stress by means of event-based sampling methods. Furthermore, it remains open to further investigation whether a more intense engagement with music in daily life can positively impact these stress-responsive systems by means of music interventions in daily life.

Author Contributions

All authors contributed to the study design. Data collection was performed by MK, SF, and JD. JS and SF conducted the bio-chemical analyses of saliva samples AL, MK, JS, and UN performed the data analysis and interpretation. AL and UN drafted the manuscript, and MK, JS, SF, and JD provided critical revisions. All authors approved the final version of the manuscript for submission. All authors agree to be accountable for all aspects of the work ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Paper VI

Linnemann, A., Thierschmidt, J., & Nater, U.M. (in press). Der Einfluss des habituellen Chill-Erlebens auf die stressreduzierende Wirkung von Musik bei chronischen Schmerzpatientinnen [The influence of the habitual experience of chills on the stress-reducing effect of music listening in female pain patients].

Musikpsychologie.

Please note: the authors have no conflict of interest.

Der Einfluss des habituellen Chill-Erlebens auf die stressreduzierende Wirkung von Musik bei chronischen Schmerzpatientinnen

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Zusammenfassung

Wir haben untersucht, ob die Fähigkeit, Chills zu erleben, mit einer besseren Emotionsregulation durch Musik verbunden ist, und ob somit Personen, die habituell (d.h. im Sinne einer Disposition) Chills erleben, eine stärkere stressreduzierende Wirkung von Musikhören im Alltag erleben. Insgesamt 30 Patientinnen mit Fibromyalgie – einem chronischen Schmerzsyndrom – wurden an 14 aufeinanderfolgenden Tage in ihrem Alltag untersucht. Fünf Mal täglich machten die Probandinnen Angaben zu Stresserleben und Musikhörverhalten und sammelten Speichelproben zur Messung von biologischen Stressmarkern. Zudem wurde der Musikpräferenzfragebogen einmalig ausgefüllt, welcher Aussagen über das habituelle Erleben von Chills erlaubt. Die stressreduzierende Wirkung von Musikhören im Alltag variiert in Abhängigkeit von dem habituellen Chill-Erleben. Dabei reagierten Probandinnen, die häufiger und intensiver Chills erleben, im Vergleich zu Personen, die seltener und weniger intensiv Chills erleben, vor allem mit einer größeren Aktivierung auf Musikhören (Varianzaufklärung 0,58% - 3,29%, $\chi^2 > 32,99$, df = 8, $p < 0,001$). In Abhängigkeit des wahrgenommenen Arousals der Musik zeigte sich, dass Probandinnen mit niedrigerer Häufigkeit des Chill-Erlebens von Musik mit einem niedrigen Arousal zur Stressreduktion profitieren. Probandinnen, die häufig Chills erleben, berichteten weniger Stress, wenn sie Musik mit einem hohen Arousal hörten (Varianzaufklärung 3,29%, $\chi^2 = 32,99$, df = 8, $p < 0,001$). Wird Musik allerdings aus dem Grund Entspannung gehört, so zeigt sich ein stressreduzierender Effekt unter Berücksichtigung der Chill-Häufigkeit. Dabei nimmt mit zunehmender Häufigkeit des habituellen Chill-Erlebens die stressreduzierende Wirkung von Musikhören aus dem Grund Entspannung ab (Varianzaufklärung 0,60%, $\chi^2 = 24,16$, df = 6, p

< 0,001), während die Sekretion des Hormons sCort am geringsten war, wenn Patientinnen, die habituell Chills erleben, Musik aus dem Grund Entspannung gehört haben (Varianzausklärung 0,89%, χ^2 = 38,17, df = 7, p < 0,001). Musik an sich ist somit nicht zu Stressreduktionszwecken bei Fibromyalgie-Patientinnen mit häufigerem und intensiverem habituellen Chill-Erleben geeignet. Es sollten insbesondere das Arousal der gehörten Musik und Gründe des Musikhörens bei Fibromyalgie-Patientinnen, die häufig und intensiv Chills erleben, berücksichtigt werden, um eine Stressreduktion durch Musikhören zu erreichen.

Abstract

We investigated whether chills are associated with more successful emotion regulation through music listening. In particular, we hypothesized that people who experience chills on a habitual basis (within the meaning of a trait) benefit to a greater extent from music listening for stress reduction purposes in daily life. Thirty female patients with fibromyalgia – a chronic pain syndrome – were examined for 14 consecutive days in their daily life. Participants rated their stress levels and music listening behavior, and provided a saliva sample for the analysis of biological stress markers five times per day. Additionally, the music preference questionnaire was completed; this instrument assesses the habitual experience of chills. The stress-reducing effect of music listening in daily life varied depending on the habitual experience of chills. Those participants who reported more frequent and more intense experiences of chills felt more activated after listening to music (explained variance 0,58% - 3,29%, χ^2 > 32,99, df = 8, p < 0,001). Participants with less frequent experiences of music-induced chills reported less stress after having listened to music that was perceived as low in arousal. Participants with more frequent experiences of chills benefitted from music that was perceived as high in arousal for stress-reducing effects (explained variance 3,29%, χ^2 = 32,99, df = 8, p < 0,001). Music listening was associated with stress-reducing effects when considering relaxation as reason for music listening and the frequency of habitual experiences of chills: With increasing frequency of habitual chill experiences, the stress-reducing effect of music listening for the reason of relaxation decreased (explained variance 0,60%, χ^2 = 24,16, df = 6, p < 0,001). However, the secretion of cortisol was lowest, when participants who habitually experience chills, reported listening to music for the reason of relaxation (explained variance 0,89%, χ^2 = 38,17, df = 7, p < 0,001). Consequently, music listening per se was not associated with a stress-reducing effect for participants with more frequent and more intense experiences of chills. However, the arousal of the music and reasons for music listening should be kept in mind when patients with fibromyalgia syndrome, who experience more frequent and more intensive chills, want to profit from music for stress reduction purposes in daily life.

1. Einleitung

1.1. Musikhören im Alltag als Mittel zur Emotionsregulation

Musikhören stellt für viele Personen eine wichtige Aktivität des täglichen Lebens dar (North, Hargreaves, & Hargreaves, 2004; Randall, Rickard, & Vella-Brodrick, 2014; Skanland, 2013). Dabei konnten Schäfer et al. (2013) drei Hauptfunktionen von Musikhören im Alltag identifizieren: Emotionsregulation (‚regulate arousal and mood'), Selbsterfahrung (‚self-awareness') und soziale Verbundenheit (‚social relatedness'). Vor allem das Musikhören zur Emotionsregulation stellt eine häufige Funktion von Musikhören im Alltag dar (van Goethem & Sloboda, 2011). Basierend auf qualitativen Interviews berichtet De Nora (1999), dass Musikhören im Alltag eingesetzt wird, um bestehende Emotionen zu verstärken, sich von bestimmten Emotionszuständen abzulenken und positive Emotionszustände zu erreichen. Befunde aus empirischen Befragungsstudien (z.B. Vorderer & Schramm, 2004) sowie experimentellen Studien (z.B. Thoma, Ryf, Mohiyeddini, Ehlert, & Nater, 2011) belegen diesen Eindruck: Menschen wählen bewusst bestimmte Musik in bestimmten Situationen, um Emotionen gezielt zu beeinflussen. Auch empirische Befunde aus ambulanten Assessment-Studien belegen diese Beobachtung: Van Goethem und Sloboda (2011) konnten zeigen, dass Musik in über drei Viertel (77,8%) der Situationen, in denen Musik gehört wurde, zur Emotionsregulation genutzt wurde. Nach den Gründen des Musikhörens im Alltag befragt, geben Proband/innen häufig emotionsregulatorische Ziele an (Juslin, Liljeström, Västfjäll, Barradas, & Silva, 2008; Linnemann, Ditzen, Strahler, Doerr, & Nater, 2015; Linnemann et al., 2015). So konnten wir beispielsweise in einer Alltags-Studie zeigen, dass Musikhören sowohl subjektiv als auch physiologisch mit einem geringeren Stresserleben einhergeht, vor allem dann, wenn Musik speziell aus dem Grund Entspannung gehört wird (Linnemann, Ditzen, et al., 2015). Juslin et al. (2008) zeigten zudem, dass nach dem Hören von Musik vermehrt positive Emotionen berichtet werden. Solche musikinduzierten Emotionen beschränken sich nicht nur auf subjektives Erleben, sondern sind bei ausreichender Stärke auch auf physiologischer Ebene messbar. Als „Gipfel der Gefühle" ist eine körperliche Reaktion in Form von sogenannten ‚Chills' beobachtbar.

1.2. Musikinduzierte Chills – Der Gipfel der Gefühle

Musikinduzierte Chills werden als eine angenehme Empfindung des Schauer-über-den-Rücken-Laufens, das gewöhnlich mit Piloerektion, also Gänsehaut, einhergeht, beschrieben (Goldstein, 1980; Maruskin, Trash, & Ellior, 2012). Das Phänomen wird als Indikator für Höhepunkte des Emotionserlebens während des Musikhörens angesehen, da physiologische Reaktionen sowie selbstberichtete Emotionen beim Erleben von Chills stärker ausfallen (Blood

& Zatorre, 2001; Grewe, Kopiez, & Altenmüller, 2009; Salimpoor, Benovoy, Larcher, Dagher, & Zatorre, 2011).

1.2.1. Die Anatomie intensiven Emotionserlebens beim Musikhören

Die erste wissenschaftliche Beschreibung von Chills stammt von Goldstein (1980). Als Definition des Phänomens übernahm er die damalige Definition von "thrills" des Oxford Dictionary: *"a subtle nervous tremor caused by intense emotion or excitement (as pleasure, fear, etc.), producing a slight shudder or tingling through the body..."* (Goldstein, 1980, S. 126). Goldstein (1980) geht davon aus, dass Chills meist vom oberen Wirbelsäulenbereich oder Nacken ausgehen, und sich dann – bei intensiverem Chill-Erleben – über Kopf, Gesicht und in die Körperperipherie ausbreiten. Messbar gemacht werden die Chills häufig anhand der elektrodermalen Aktivität, einem Marker für die Aktivität des autonomen Nervensystems, da das Erleben von Chills häufig mit einem Anstieg der elektrodermalen Aktivität einher geht (Benedek & Kaernbach, 2011; Craig, 2005; Grewe, Nagel, Kopiez, & Altenmüller, 2007). Dabei können Chills von einer Reihe externaler Stimuli (z.B. akustisch, visuell, taktil, gustatorisch), aber auch von internalen Stimuli (z.B. mentale Vorstellungen) ausgelöst werden (Grewe, Katzur, Kopiez, & Altenmüller, 2011). Die durch externale Stimuli ausgelösten Chills ähneln sich in ihrer physiologischen Manifestation. Im Kontext der musikinduzierten Chills hat sich die elektrodermale Aktivität zwar als guter Marker erwiesen (Craig, 2005), jedoch geht das Erleben von Chills nicht immer mit einer Veränderung der elektrodermalen Aktivität einher, denn durch mentale Vorstellungen ausgelöste Chills sind nur mittels Selbstauskunft messbar (Grewe, et al., 2011). Weiter sei darauf hingewiesen, dass sich Veränderungen in der elektrodermalen Aktivität nicht spezifisch beim Erleben von Chills zeigen, sondern auch bei anderem emotionalen Erleben auftreten können (Krumhansl, 1997).

1.2.2. Wer erlebt Chills?

Keineswegs erlebt jeder Mensch Chills, sondern es scheint vielmehr das Gegenteil der Fall zu sein: Empirische Daten zum Chill-Erleben deuten darauf hin, dass dieses inter- und intraindividuell höchst variabel ist. Beispielsweise variiert der Prozentsatz an Personen, die Chills erleben, und denen, die keine erleben, je nach Studie, enorm (Nusbaum & Silvia, 2011). In einer experimentellen Studie von Benedek und Kaernbach (2011) zeigten weniger als die Hälfte der Proband/innen (40%) physiologisch messbare Chills in Reaktion auf Musik, während in einer Studie von Grewe et al. (2007) der Prozentsatz an Chill-Respondern bei 55% (21 von 38) lag. In einer Studie von Craig (2005) zeigten sogar 90% (27 von 30) der Proband/innen musikinduzierte Chills. Aber nicht nur der Prozentsatz an Personen, die Chills erleben, variiert von Studie zu Studie, sondern auch die Häufigkeit und Intensität, mit der Personen Chills in

Reaktion auf bestimmte Stimuli zeigen. Beispielsweise variierte in einer Studie von Grewe et al. (2009) die Häufigkeit des Chill-Erlebens zwischen 0 und 88 Chills pro Person. Diese hohe interindividuelle Variabilität hinsichtlich des Erlebens von Chills legt die Vermutung nahe, dass das Erleben von Chills sowohl eine habituelle (trait) als auch eine situative (state) Komponente aufweist (Nusbaum & Silvia, 2011). Ein Großteil der Forschung befasst sich allerdings mit dem Auftreten von situativen Chills, obwohl gerade situative Faktoren im Vergleich zu stabilen Personenmerkmalen einen relativ geringen Anteil an Varianz im Auftreten von Chills erklären (Nusbaum & Silvia, 2011).

Bezüglich situativer Einflussfaktoren auf das Erleben von musikinduzierten Chills weiß man, dass die Valenz der Musik eine Rolle zu spielen scheint. Unklar ist allerdings die Richtung dieser Wirkbeziehung: Während Panksepp (1995) zeigte, dass das Auftreten von Chills mit der Traurigkeit von Musikstücken assoziiert ist, zeigten Grewe et al. (2011), dass Chills häufiger durch fröhliche Musik ausgelöst werden.

Chills als eine Disposition zu betrachten hat eine lange Tradition. Mechanismen, die zu ihrem Erleben führen, werden dagegen erst seit Kurzem untersucht (Colver & El-Alayli, 2015; Grewe, et al., 2007; Kunkel, Pramstaller, Grant, & von Georgi, 2008). Ausgehend von der Beobachtung, dass es keine eindeutige Reiz-Reaktion-Beziehung beim Erleben von Chills gibt, stellen Grewe et al. (2007) ein Modell auf, in dem neben bestimmten Charakteristika der Musik (z.B. Einsetzen einer Singstimme) auch Charakteristika der Person mit dem Auftreten von Chills in Verbindung gebracht werden. Erste Ergebnisse deuten darauf hin, dass das Vorkommen von Chills vor allem mit der Ausprägung auf der Persönlichkeitsdimension ‚Offenheit für Erfahrungen' assoziiert ist (Colver & El-Alayli, 2015; Kunkel, et al., 2008; Nusbaum & Silvia, 2011). Dabei erleben Personen mit einer höheren Ausprägung auf der Persönlichkeitsdimension ‚Offenheit für Erfahrungen' häufiger musikinduzierte Chills. Kunkel et al. (2008) fanden zudem anhand einer Befragungsstudie Zusammenhänge zwischen dem Erleben von Chills und der Ausprägung auf den Persönlichkeitsdimensionen Neurotizismus und Extraversion. Grewe et al. (2007) konnten zeigen, dass Personen mit einer niedrigeren Sensation Seeking-Ausprägung eher Chills erleben. Auch die Belohnungssensitivität spielt eine Rolle, denn Personen mit höherer Belohnungssensitivität erleben eher Chills (Grewe, et al., 2007). Uneinheitlich ist das Befundmuster hinsichtlich möglicher Geschlechterunterschiede: Während Panksepp (1995) Geschlechterunterschiede fand, konnten Grewe et al. (2007) keine Unterschiede finden. Insgesamt scheint die Fähigkeit, Chills zu erleben, nicht mit sozio- und musikdemographischen Aspekten wie Alter oder musikalischer Erfahrung zu tun zu haben. Stattdessen unterscheiden sich Menschen, die Chills erleben, in der Art und Weise, wie sie Musik nutzen von Personen, die keine Chills erleben. So messen Personen, die Chills erleben, Musik eine größere Wichtigkeit im Leben bei, identifizieren sich stärker mit ihrer präferierten Musik, und hören im Alltag häufiger Musik als Personen, die keine Chills erleben (Grewe, et al., 2009; Grewe, et al., 2007; Nusbaum & Silvia, 2011).

Zusammenfassend lässt sich feststellen, dass musikinduzierte Chills wohl in Wechselwirkungen zwischen Person, Musik und Situation entstehen. Zwar ist bekannt, dass sich Personen, die Chills erleben, deskriptiv von Personen unterscheiden, die keine Chills erleben, unklar ist aber, ob Musikhören bei Personen, die habituell Chills erleben, eine andere Wirkung erzielt als bei Personen, die keine Chills erleben. Auch basieren Untersuchungen bislang auf Vergleichen zwischen Personen, die Chills erleben mit Personen, die keine Chills erleben. Somit wird von einem kategorialen Ansatz ausgegangen, obwohl sich Personen jedoch auch dimensional in der Häufigkeit und Intensität ihres Chill-Erlebens unterscheiden.

Da sich musikinduzierte Chills als körperlich spürbarer Ausdruck intensiven emotionalen Erlebens während des Musikhörens äußern, liegt die Vermutung nahe, dass Personen, die habituell (häufiger und intensiver) Chills erleben, besonders emotional auf Musik reagieren, und daher besser in der Lage sind, ihre Emotionen mittels Musik zu beeinflussen. Gerade vor dem Hintergrund, dass Entspannung einen häufigen Grund des Musikhörens darstellt (Linnemann, Ditzen, et al., 2015; Linnemann, Kappert, et al., 2015), stellt sich die Frage, ob das habituelle Erleben von Chills die stressreduzierende Wirkung von Musik beeinflussen kann.

1.3. Die stressreduzierende Wirkung von Musikhören im Alltag

Stress stellt einen negativen psychobiologischen Zustand dar, der als Risikofaktor für die Entstehung und Aufrechterhaltung psychischer und körperlicher Erkrankungen gilt (Chrousos, 2009). Andere und auch wir nehmen an, dass die positiven Effekte von Musikhören auf die Gesundheit über Stressreduktion vermittelt sein könnten (Thoma & Nater, 2011). Allerdings wurden die meisten Studien dazu bislang experimentell im Labor durchgeführt, so dass wenig Wissen und Konsens darüber besteht, von welchen Personen-, Musik- und Situationsmerkmalen dieser Effekt im Alltag beeinflusst wird.

Die physiologische Stressantwort wird durch stress-sensitive Systeme im Körper reguliert, unter anderem durch das autonome Nervensystem (ANS) und die Hypothalamus-Hypophysen-Nebennierenrinde-Achse (HHNA). Musikhören hat sich in einer Reihe von Studien als stressreduzierend erwiesen, sowohl was subjektives Stresserleben als auch die Aktivität des ANS und der HHNA angeht (Chanda & Levitin, 2013; Kreutz, Murcia, & Bongard, 2012; Thoma & Nater, 2011). Allerdings ist unklar, welche moderierenden Einflüsse auf diese Beziehung wirken. Studien weisen darauf hin, dass dem Arousal der gehörten Musik dabei eine besondere Rolle zukommt. So zeigte sich, dass vor allem entspannende Musik stressreduzierend wirkt (Chanda & Levitin, 2013). Aber auch die Gründe des Musikhörens scheinen von Bedeutung zu sein, da gerade Musik, die aus dem Grund Entspannung gehört wird, unabhängig von der Valenz und dem Arousal der gehörten Musik, Stress reduziert (Linnemann, Ditzen, et al., 2015). Neben dem Arousal und den Gründen des Musikhörens spielt auch die erlebte Stressintensität eine Rolle. Sowohl in experimentellen Studien (Thoma et al., 2013) als auch in Alltag-Studien (Linnemann, Ditzen, et al., 2015; Linnemann, Kappert, et al., 2015) scheint der stressreduzierende Effekt des bloßen Musikhörens in Abhängigkeit des Stresserlebens begrenzt zu sein. Beispielsweise zeigte sich bei Patientinnen mit Fibromyalgie-Syndrom (FMS), einer medizinisch unerklärten chronischen Schmerzerkrankung, kein stressreduzierender Effekt von Musikhören im Alltag, obwohl angegeben wurde, dass Musik häufig aus dem Grund Entspannung gehört wurde (Linnemann, Kappert, et al., 2015). Vor dem Hintergrund, dass Stress neben der Auslösung auch zur Aufrechterhaltung dieses Syndroms beiträgt, ist es hier dringend vonnöten, stressreduzierende Maßnahmen für diese chronisch gestresste Patienten-Stichprobe zu finden. Zwar hat sich Musikhören (im Alltag) als eine erfolgversprechende adjuvante, nicht-pharmakologische Behandlungsform herausgestellt, allerdings lag bislang der Fokus der Forschungsbemühungen auf einer verbesserten Symptomkontrolle in Form von geringerem Schmerzerleben (Garza-Villarreal et al., 2015; Guetin et al., 2012; Onieva-Zafra, Castro-Sánchez, Matarán-Peñarrocha, & Moreno-Lorenzo, 2013), verbesserter Mobilität (Garza-Villarreal et al., 2014) und erhöhter Schlafqualität (Picard et al., 2014). Unklar ist, unter welchen Bedingungen Musikhören bei Patient/innen mit FMS auch eine stressreduzierende Wirkung haben kann.

1.4. Fragestellung: Musik, Chills und Stress – Begünstigt die Fähigkeit, habituell Chills zu erleben, die stressreduzierende Wirkung von Musik bei chronischen Schmerzpatientinnen?

Musikhören wird häufig zur Emotionsregulation im Alltag eingesetzt. Das Erleben von Chills scheint dabei mit dem Erleben von starken, positiven Emotionen während des Musikhörens assoziiert zu sein. Es stellt sich somit die Frage, ob die Fähigkeit, Chills zu erleben, mit einer besseren Emotionsregulation durch Musik verbunden ist. Gerade vor dem Hintergrund, dass Musik häufig aus dem Grund Entspannung gehört wird, stellt sich die Frage, ob Personen, die habituell Chills erleben, somit eine stärkere stressreduzierende Wirkung von Musikhören im Alltag erleben, und von welchen Faktoren dieser Effekt abhängt. Aufbauend auf den Befunden von Linnemann, Kappert et al. (2015), die keine stressreduzierende Wirkung von Musikhören bei Fibromyalgie-Patientinnen im Alltag finden konnten, soll nun untersucht werden, ob sich durch die Berücksichtigung des habituellen Chill-Erlebens als einer Moderatorvariable ein stressreduzierender Effekt in dieser Stichprobe zeigen lässt. Die folgenden Hypothesen werden untersucht:

Hypothese 1: Das Erleben von Chills geht mit einer größeren Stressreduktion durch Musikhören bei chronischen Schmerzpatientinnen einher.

Hypothese 2: Das Erleben von Chills geht in Abhängigkeit von Valenz und Arousal der gehörten Musik mit einer größeren Stressreduktion durch Musikhören bei chronischen Schmerzpatientinnen einher.

Hypothese 3: Das Erleben von Chills geht in Abhängigkeit von den Gründen des Musikhörens mit einer größeren Stressreduktion durch Musikhören bei chronischen Schmerzpatientinnen einher.

2. Methode

2.1 Stichprobe

Die untersuchte Stichprobe bestand aus N = 30 FMS-Patientinnen, die im Mittel $\bar{x} = 50{,}7 \pm 9{,}9$ Jahre (Range: 27 bis 64) alt waren. Die Probandinnen wurden über Zeitungsanzeigen, Aushänge in Arztpraxen und Selbsthilfegruppen in Marburg und Umgebung rekrutiert. Es wurden explizit nur Frauen angesprochen, um eine Konfundierung durch Geschlechtereffekte auszuschließen (Lange, Karpinski, Krohn-Grimberghe, & Petermann, 2010). Eingeschlossen wurde, wer zwischen 18 und 65 Jahre alt war, fließend Deutsch sprach und die FMS-Forschungskriterien (modifiziert nach den ACR 2010 Diagnosekriterien) erfüllte (Wolfe et al., 2010). Dies beinhaltete entweder einen Wert von ≥ 7 auf dem *Widespread Pain Index* (WPI: Häuser et al., 2010) und Werte ≥ 5 auf der Symptom Severity Scale (SSS: Wolfe, et al., 2010) oder einen Wert zwischen 3 und 6 im WPI und einen Wert von ≥ 9 in der SSS (Wolfe et al., 2011).
Ausgeschlossen wurden schwangere oder stillende Frauen, solche mit unregelmäßigem Menstruationszyklus, sowie Frauen mit Body-Mass-Index (BMI) über 30 kg/m². Auch durften die Probandinnen unter keiner schwerwiegenden psychischen Erkrankungen leiden bzw. gelitten haben (Ausschlusskriterien waren: aktuell vorliegende depressive Episode, Substanzmissbrauch innerhalb der letzten beiden Jahre, Essstörung innerhalb der letzten fünf Jahre, jemals Schizophrenie/wahnhafte Störungen, jemals bipolare affektive Störungen) oder körperliche Erkrankungen, die die Symptome besser erklären könnten (z.B. chronische entzündliche Erkrankungen).

2.1 Studien-Design

Die Daten wurden im Rahmen einer größeren Alltags-Studie zum Thema „Stress und körperliche Beschwerden“ erhoben. Eine umfassende Darstellung der Studie und des Designs findet sich in Linnemann, Kappert et al. (2015), wo auch die Ergebnisse zu den Effekten des Musikhörens auf das Schmerz- und Stresserleben berichtet werden. Allerdings wurde in

Linnemann, Kappert el al. (2015) das habituelle Chill-Erleben nicht als mögliche Moderatorvariable betrachtet. Der stressreduzierende Effekt von Musikhören bei Patientinnen mit Fibromyalgie-Syndrom unter Berücksichtigung des habituellen Chill-Erlebens ist deshalb Gegenstand der hier vorliegenden Untersuchung.

Die Probandinnen wurden in ihrem Alltag anhand eines *Ecological Momentary Assessment* (EMA)-Designs untersucht (Shiffman, Stone, & Hufford, 2008). Für die Dauer von 14 aufeinanderfolgenden Tagen erhielten die Probandinnen einen iPod touch ® und wurden gebeten, sechs Mal täglich (direkt nach dem Erwachen, 30 Minuten nach dem Erwachen, 11 Uhr, 14 Uhr, 18 Uhr, 21 Uhr) Angaben zu ihrem momentanen Stresserleben sowie zum Musikhören seit dem letzten Messzeitpunkt zu tätigen. Auch sammelten die Probandinnen zu jedem Messzeitpunkt eine Speichelprobe zur Messung von biologischen Stressmarkern (Cortisol als Marker für die Aktivität der HHNA sowie Alpha-Amylase als Marker für die Aktivität des ANS). Studienbegleitend wurden Fragebögen zur Erfassung des habituellen Chill-Erlebens sowie zu symptombezogenen Aspekten erhoben. Jede Probandin erhielt eine Aufwandsentschädigung in Höhe von 80 Euro. Für die Studie liegt ein positives Votum der Ethikkommission der Philipps-Universität Marburg vor (Aktenzeichen 2012-50K).

2.3 Erfasste Konstrukte

Tabelle 1 Übersicht über die erfassten Konstrukte und deren Operationalisierung

		Ecological Momentary Assessment					Selbstauskunft -inventare
		+ 30	10 Uhr	11 Uhr	14 Uhr	21 Uhr	einmalig
Chill-Erleben	Häufigkeit						x
	Intensität						x
Musikhörverhalten							
	Musikhören (ja/nein)	x	x	x	x	x	
	Valenz	x	x	x	x	x	
	Arousal	x	x	x	x	x	
	Grund des Musikhörens	x	x	x	x	x	
Stress	Subjektives Stresserleben	x	x	x	x	x	
	Cortisol	x	x	x	x	x	
	Alpha-Amylase	x	x	x	x	x	
FMS Symptomatik	FIQ						x
Kontrollvariablen	CTQ						x
	BMI						x

Anmerkungen: *+ 30: 30 Minuten nach dem Erwachen; FIQ: Fibromyalgia Impact Questionnaire, CTQ: Childhood Trauma Questionnaire, BMI: Body-Mass-Index, X: Messung vorhanden*

2.3.1. Erfasste Konstrukte im Rahmen des *Ecological Momentary Assessments*

2.3.1.1. Musikhörverhalten

Die Abfrage des individuellen Musikhörverhaltens begann mit der Frage, ob seit dem letzten Eintrag willentlich Musik gehört wurde. Dies bedeutet, dass die Probandinnen sich selbst initiativ dazu entschieden haben sollten, Musik zu hören. Wichtig dabei ist, dass der Musik bewusst zugehört wurde. Die Antwort auf diese Frage konnte entweder Ja oder Nein lauten. Nur im Falle einer Ja-Antwort wurden die nachfolgenden Fragen zur Musik gestellt, ansonsten folgten zu diesem Messzeitpunkt keine weiteren Fragen zum Musikhörverhalten.

Anhand der beiden Dimensionen des Circumplex Modells von Russell (1980) wurde die gehörte Musik durch die Probandinnen eingeschätzt. Die erste Dimension bezeichnet die wahrgenommene Valenz der Musik, die zwischen den beiden Polen traurig (0) und fröhlich (100) variieren kann. Die zweite Dimension beschreibt das wahrgenommene Arousal der Musik, und kann zwischen den beiden Polen beruhigend (0) und energetisierend (100) variieren. Haben die Versuchspersonen mehrere Musikstücke gehört, sollten sie die Einordnung so vornehmen, dass sie der Mehrheit der Musikstücke entspricht.

Basierend auf empirischen Befunden zu den Gründen des Musikhörens im Alltag (Juslin, et al., 2008; Linnemann, Thoma, & Nater, 2015) sowie in Einklang mit einer bereits durchgeführten EMA-Studie (Linnemann, Ditzen, et al., 2015), wurden folgende vier Gründe als Antwortoption auf die Frage nach den Gründen des Musikhörens in die täglichen Abfragen implementiert: Entspannung, Aktivierung, Ablenkung und gegen Langeweile. Bei jedem Grund gab es die Möglichkeit, entweder mit *Ja* oder *Nein* zu antworten. Der Instruktion zu Folge sollte der Hauptgrund angeben werden, aus dem Musik gehört wurde. Mehrfachnennungen sowie Verneinungen aller möglichen vier Gründe waren dabei zugelassen.

2.3.1.1Stress

Als Operationalisierung für momentan erlebten Stress wurde das fünf-stufige Item „Momentan fühle ich mich gestresst“ in die täglichen Abfragen implementiert, welches auf einer Skala von gar nicht (0) bis sehr (4) beantwortet werden konnte. Die Erfassung von subjektivem Stress anhand eines Items kann psychometrisch als valide und reliabel betrachtet werden (Elo, Leppanen, & Jahkola, 2003).

Als biologische Stressmarker wurde die Aktivität des Enzyms Alpha-Amylase (sAA) sowie die Sekretion des Hormons Cortisol (sCort) gemessen. sCort kann dabei als ein Marker für die Aktivität der HHNA angesehen werden, während sAA die Aktivität des ANS widerspiegelt. In laborexperimentellen Studien konnte Musikhören mit einer Herunterregulierung der Aktivität der HHNA sowie einer Herunterregulierung des ANS in Verbindung gebracht werden (für eine Übersicht: Hodges 2011; Kreutz, et al., 2012). Bislang ist jedoch unklar, ob die Befunde aus laborexperimentellen Studien auf den Alltag übertragbar sind und inwiefern das Musikhören im Alltag einen Effekt auf diese beiden stress-sensitiven Systeme hat. Um Aussagen über mögliche mittelfristige Effekte des Musikhörens im Alltag zu ermöglichen, haben wir daher zeitversetzt die Effekte von vorherigem Musikhören auf die beiden Stressmarker sCort und sAA gemessen.

Beide Stressmarker können valide und reliabel im Speichel gemessen werden (Nater, Skoluda, & Strahler, 2013). Zur Bestimmung dieser Stressmarker im Speichel erhielten die Probandinnen SaliCaps® – beschriftete Plastikröhrchen, in die sie nach jedem Messzeitpunkt für zwei Minuten akkumulierten Speichel abgeben sollten. Die Speichelproben wurden nach Beendigung der 14-tägigen Erhebungsphase bei -20°C im Biochemischen Labor der Klinischen Biopsychologie, Marburg, bis zur Analyse gelagert. Die Analysen bezüglich der Sekretion von sCort erfolgten anhand eines kommerziell erhältlichen *Enzyme Linked Immunosorbent Assay* (ELISA) (IBL, Hamburg, Germany). Die Aktivität des Enzyms sAA wurde anhand eines *Kinetic Colorimetric* Tests und Reagenzien von Roche (Fa. Roche Diagnostics, Mannheim, Germany) gemessen.

2.3.2. Erfasste Konstrukte anhand der Selbstauskunfts-Inventare

2.3.2.1. Habituelles Chill-Erleben

Das habituelle Chill-Erleben wurde anhand des Musikpräferenzfragebogens (MPQ; Nater, Krebs, & Ehlert, 2005) erfasst. Dieser Fragebogen besteht neben Items zu bevorzugten Musikstilen, bevorzugten Gründen des Musikhörens und bevorzugten Situationen, in denen Musik gehört wird, aus Items, die die Bedeutsamkeit von Musik für das eigene Leben, momentanes und vergangenes Musizieren, sowie das habituelle Chill-Erleben abfragen. Dabei werden Fragen zur Häufigkeit des Chill-Erlebens (Skala 0 (gar nicht) bis 4 (fast immer)) sowie zur Intensität des Chill-Erlebens (Skala 0 (kaum spürbar) bis 4 (überwältigend stark)) gestellt. Chills werden dabei wie folgt definiert: *‚Chills sind körperliche Reaktionen, ein Schaudern oder Frösteln, das sich vom Kopf her über den Rücken und/oder andere Teile des Körpers ausbreitet.‘* Bei der Angabe wurden die Probandinnen gebeten, sich auf Chills zu beschränken, welche ausschließlich beim Musikhören erlebt werden.

2.3.2.2. Fibromyalgia Impact Questionnaire (FIQ: Burckhardt, Clark, & Bennett, 1991)

Der *Fibromyalgia Impact Questionnaire* (FIQ) erfasst anhand von zehn Items den derzeitigen Gesundheitsstatus von FMS-Patient/innen. Berücksichtigt werden dabei Symptome, körperliche Aktivitäten, Arbeitsfähigkeit und Wohlbefinden. Der Gesamtwert kann zwischen 0 und 100 variieren, wobei ein höherer Wert eine größere Beeinträchtigung anzeigt.

2.3.2.3. Childhood Trauma Questionnaire (CTQ: Klinitzke, Romppel, Hauser, Brahler, & Glaesmer, 2012)

Der *Childhood Trauma Questionnaire* (CTQ) stellt ein Selbstbeurteilungsinstrument zur retrospektiven Erfassung von traumatischen Erfahrungen in Kindheit und Jugend dar. Anhand von 31 Items werden Beispiele von sexuellem, körperlichem und emotionalem Missbrauch sowie körperlicher und emotionaler Vernachlässigung in Kindheit und Jugend abgefragt. Die Antworten werden auf einer 5-stufigen Likert-Skala erfasst, die von überhaupt nicht (1) bis sehr häufig (5) reicht, wobei höhere Werte ein höheres Ausmaß an Misshandlungen und Vernachlässigung beschreiben.

In empirischen Studien hat sich gezeigt, dass kindliche Traumata (z.B. Misshandlung und/oder Vernachlässigung) einen psychosozialen Risikofaktor für das Auftreten von Fibromyalgie darstellen (Walker et al., 1997). Auch stellen Kindheitstraumata einen Prädiktor für neuroendokrine Veränderungen bei Patient/innen mit Fibromyalgie dar (Weissbecker, Floyd, Dedert, Salmon, & Sephton, 2006), so dass in sämtlichen Analysen für den Summenwert im CTQ kontrolliert wird.

2.4 Statistische Herangehensweise

Zur Überprüfung aller Hypothesen wurden hierarchisch lineare Modelle anhand der Software HLM7 (Raudenbush, Bryk, & Congdon, 2004) berechnet, da die Daten auf Personenebene (Level-2) und auf der Ebene der einzelnen Messzeitpunkte (Level-1) hierarchisch strukturiert sind.

Die abhängige Variable (AV) stellt Stresserleben dar, operationalisiert anhand der subjektiven Einschätzung des momentanen Stresserlebens, der Aktivität des Enzyms sAA sowie der Sekretion des Hormons sCort. Da sCort- und sAA-Werte nicht normalverteilt sind, wurden sie anhand der Formel ln (x) + 10 logarithmiert. Kontrollvariablen sind die Summenwerte im FIQ und CTQ. In Analysen, die biologische Parameter enthalten, wurde zusätzlich aufgrund der tageszeitbedingten Variationen von sCort und sAA für den Messzeitpunkt kontrolliert (Kirschbaum & Hellhammer, 1994; Nater, Rohleder, Schlotz, Ehlert, & Kirschbaum, 2007). Auch wurde aufgrund des Einflusses des BMI auf die Aktivität der HHNA für den BMI kontrolliert (Champaneri et al., 2013). Die unabhängigen Variablen (UV) sind:

Musikhörverhalten (Valenz, Arousal, Gründe des Musikhörens), die Chill-Häufigkeit, die Chill-Intensität sowie die Interaktionen aus den Variablen des Musikhörverhaltens und den Chill-Variablen.

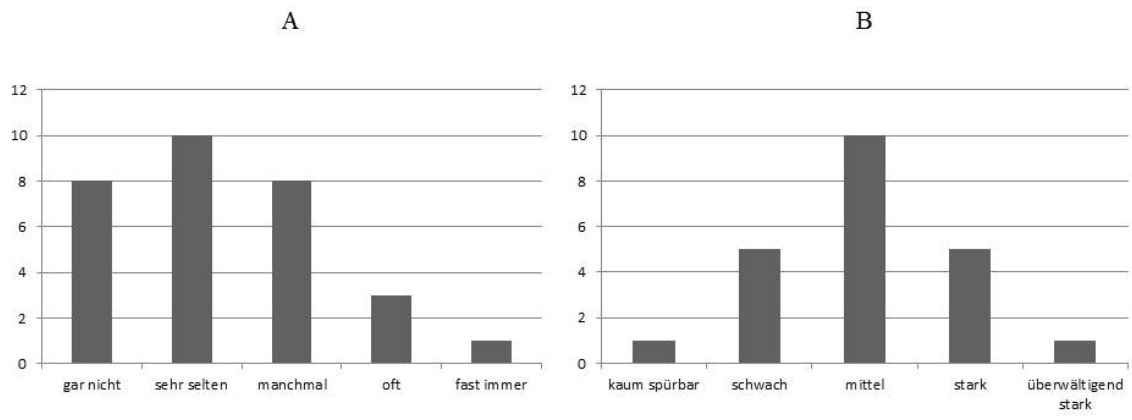
Die Berechnungen erfolgten anhand von Modellvergleichen zwischen einem unbedingten Nullmodell, welches nur die abhängige Variablen sowie die Kontrollvariablen enthält, und einem bedingten Modell, welches die interessierenden unabhängigen Variablen enthält (Woltman, Feldstain, MacKay, & Rocchi, 2012). Hierauf basierend wurden im nächsten Schritt bedingte Modelle definiert, bei denen die AV auf Level-1 durch die Hinzunahme der interessierenden UVs weiter spezifiziert wurde. So wurde zunächst überprüft, ob die AVs durch die UVs Chill-Häufigkeit, Chill-Intensität sowie durch Musikhören an sich (Hypothese 1), Valenz und Arousal der gehörten Musik (Hypothese 2), Gründe des Musikhören (Hypothese 3) sowie der Interaktion aus Chill-Variablen und Musikvariablen besser vorhergesagt werden können.

In allen Berechnungen wurde die Signifikanz anhand der konservativeren Schätzung der Modellparameter mit robusten Standardfehlern überprüft. Die Modellschätzung basiert auf dem Full Maximum Likelihood-Verfahren. Die Verbesserung der Vorhersage der AV durch das bedingte Modell gegenüber dem unbedingten Nullmodell wurde mittels χ^2-Statistik geprüft. Im Einklang mit Singer und Willett (2003) wurde dabei Pseudo-R^2 als Indikator der erklärten Varianz beschrieben. Die Berechnung von Pseudo-R^2 erfolgte dabei anhand folgender Gleichung: $PseudoR^2 = ((\sigma^2(Nullmodell) - \sigma^2(bedingtes\ Modell)) / \sigma^2(Nullmodell))$. Die Berechnung und Interpretation von Interaktionen erfolgte in Einklang zu Preacher, Curran und Bauer (2006). In allen Analysen werden unstandardisierte Koeffizienten (UC), Standardfehler (SE), sowie Freiheitsgrade (df) berichtet. Das generelle Signifikanzniveau wurde auf $p < 0{,}05$ festgelegt.

3. Ergebnisse

Von den 30 Probandinnen gaben acht (26,7%) an, niemals Chills zu erleben. Somit konnten 22 Probandinnen (73,3%) als Chill-Responder identifiziert werden. Die durchschnittliche Intensität des Chill-Erlebens betrug $\bar{x} = 2{,}00 \pm 0{,}93$. Eine genaue Verteilung der Häufigkeit und Intensität des Chill-Erlebens kann Abbildung 1 entnommen werden. Ein Überblick über die deskriptiven Daten in Abhängigkeit des Chill-Erlebens befindet sich in Tabelle 2.

Abbildung 1 Häufigkeit (A) und Intensität (B) des habituellen berichteten Chill-Erlebens



3.1 Unterschiede im Musikhörverhalten in Abhängigkeit von dem habituellen Chill-Erleben

Die Häufigkeit des habituellen Chill-Erlebens war mit der Valenz und dem Arousal der gehörten Musik korreliert: Je häufiger die Probandinnen angaben, Chills zu erleben, desto trauriger und energetisierender war die Musik, die sie im Alltag hörten. Die Intensität des Chill-Erlebens war weder mit der Valenz noch mit dem Arousal der gehörten Musik assoziiert. Es zeigten sich allerdings Unterschiede hinsichtlich der Gründe des Musikhörens in Abhängigkeit von dem habituellen Chill-Erleben: Personen, die häufiger habituell Chills erleben, gaben häufiger an, Musik aus den Gründen Entspannung und Ablenkung zu hören. Dagegen gaben sie seltener an, Musik aus dem Grund Aktivierung zu hören. Hinsichtlich der Intensität des Chill-Erlebens ergab sich folgendes Muster: Personen, die intensiver Chills erleben, gaben ebenfalls häufiger an, Musik aus den Gründen Entspannung und Ablenkung zu hören. Zusätzlich gaben Personen, die habituell intensiver Chills erleben, häufiger an, Musik aus dem Grund Aktivierung zu hören. Ein Überblick über alle Korrelationen zwischen den einzelnen in dieser Studie erfassten Variablen befindet sich in Tabelle 3.

3.2 Hypothese 1: Das Erleben von Chills geht mit einer größeren Stressreduktion durch Musikhören bei chronischen Schmerzpatientinnen einher.

Anhand der ersten Hypothese wurde zunächst untersucht, inwiefern die Häufigkeit des Chill-Erlebens die stressreduzierende Wirkung von Musik beeinflusst. Hierbei zeigten sich keine signifikanten Zusammenhänge zwischen den UVs und dem subjektiven Stresserleben: Weder Musikhören an sich ($UC = -0{,}06$, $t(1917) = -0.745$, $p = 0{,}456$), noch die Häufigkeit des Chill-Erlebens ($UC = -0{,}02$, $t(1917) = -0{,}03$, $p = 0{,}781$), noch die Interaktion aus Musikhören und

Häufigkeit des Chill-Erlebens (UC = 0,04, $t(1917) = 0{,}658$, $p = 0{,}511$) hatten einen signifikanten Einfluss auf das subjektive Stresserleben.

In einem nächsten Schritt wurden die biologischen Stressmarker sCort und sAA als AVs betrachtet. Es waren weder das Musikhören an sich (UC = 0,04, $t(1803) = 0{,}608$, $p = 0{,}543$), noch die Häufigkeit des Chill-Erlebens (UC = 0,00, $t(1803) = 0{,}075$, $p = 0{,}940$), noch die Interaktion aus Musikhören und Häufigkeit des Chill-Erlebens (UC = −0,04, $t(1803) = -0{,}804$, $p = 0{,}421$) mit der Sekretion des Hormons sCort assoziiert. Das gleiche gilt für die Aktivität des Enzyms sAA (Musikhören: UC = −0,00, $t(1803) = -0{,}011$, $p = 0{,}991$, Chill-Häufigkeit: UC = −0,23, $t(1803) = -1{,}707$, $p = 0{,}088$, Interaktion: UC = 0,03, $t(1803) = 0{,}497$, $p = 0{,}619$).

In Analogie zu diesen Modellen wurde in einem nächsten Schritt die Intensität des Chill-Erlebens in Bezug auf die stressreduzierende Wirkung von Musik untersucht. In diese Analysen konnten nur die 22 der Probandinnen eingehen, die angaben, Chills zu erleben. Nur bezüglich der Aktivität von sAA zeigten sich signifikante Zusammenhänge: Unter Berücksichtigung der Chill-Intensität zeigte sich, dass Musikhören an sich mit einer niedrigeren Aktivität des Enzyms sAA nach dem Musikhören einherging (UC = −0,23, $t(1350) = -2{,}183$, $p < 0{,}001$). Zudem zeigte sich eine signifikante Interaktion aus Musikhören und der Intensität des Chill-Erlebens (UC = 0,12, $t(1350) = 2{,}815$, $p = 0{,}005$), dahingehend, dass Personen, die eine hohe Chill-Intensität erleben, die höchste Aktivität von sAA zeigen, wenn sie Musik hören. Dabei werden 0,58% der Varianz in der Aktivität des Enzyms sAA durch die Interaktion aus Musikhören und Chill-Intensität erklärt ($\chi^2 = 36{,}83$, df = 8, $p < 0{,}001$).

3.2 Hypothese 2: Das Erleben von Chills geht in Abhängigkeit von Valenz und Arousal der gehörten Musik mit einer größeren Stressreduktion durch Musikhören bei chronischen Schmerzpatientinnen einher.

In einem nächsten Schritt wurde untersucht, ob der Einfluss des Chill-Erlebens auf die stressreduzierende Wirkung von Musik durch die Valenz und das Arousal der gehörten Musik beeinflusst wird. Da zwei Probandinnen nie Musik gehört haben, gehen in die nachfolgenden Analysen n = 28 Probandinnen ein.

<u>Tabelle 2</u> Deskriptive Übersicht über subjektives Stressempfinden, Valenz und Arousal der gehörten Musik sowie über die angegebenen Gründe des Musikhörens in Abhängigkeit des Chill-Erlebens

		Momentan fühle ich mich gestresst[a]		Ich habe seit dem letzten MZP Musik gehört	Valenz[b]		Arousal[b]		Entspannung		Aktivierung		Ablenkung		Gegen Langeweile	
		$\overline{x}$	SD	Ja	$\overline{x}$	SD	$\overline{x}$	SD	Nein	Ja	Nein	Ja	Nein	Ja	Nein	Ja
Chill-Häufigkeit	gar nicht	1,69	0,98	11,9%	80,88	12,53	55,00	23,93	81,5%	18,5%	67,7%	32,3%	50,8%	49,2%	92,3%	7,7%
	sehr selten	1,27	1,19	21,5%	73,83	15,57	61,66	25,59	50,0%	50,0%	67,4%	32,6%	86,2%	13,8%	86,2%	13,8%
	manchmal	1,39	0,94	22,7%	69,34	13,13	60,15	20,07	67,0%	33,0%	73,0%	27,0%	55,7%	44,3%	76,5%	23,5%
	oft	1,60	0,86	21,9%	64,51	12,47	54,47	21,20	27,9%	72,1%	79,1%	20,9%	86,0%	14,0%	100,0%	0,0%
	fast immer	2,15	0,55	91,4%	75,32	8,36	77,09	7,89	1,9%	98,1%	98,1%	1,9%	34,0%	66,0%	100,0%	0,0%
Chill-Intensität	kaum spürbar	1,00	1,02	59,1%	78,51	7,39	77,31	9,51	30,8%	69,2%	69,2%	30,8%	100,0%	0,0%	100,0%	0,0%
	schwach	1,68	1,18	12,2%	78,13	13,21	65,98	27,16	65,0%	35,0%	55,0%	45,0%	72,5%	27,5%	85,0%	15,0%
	mittel	1,29	1,02	20,2%	65,48	16,61	54,06	22,48	46,4%	53,6%	76,8%	23,2%	72,8%	27,2%	76,8%	23,2%
	stark	1,26	0,95	27,8%	71,36	11,25	58,22	21,88	67,4%	32,6%	71,7%	28,3%	66,3%	33,7%	88,0%	12,0%
	überwältigend stark	2,15	0,55	91,4%	75,32	8,36	77,09	7,89	1,9%	98,1%	98,1%	1,9%	34,0%	66,0%	100,0%	0,0%

Anmerkungen: MZP = Messzeitpunkt; [a] Skala von 0 = überhaupt nicht gestresst bis 4 = sehr gestresst; [b] Visuelle Analogskala: 0 = traurig bzw. beruhigend, 100 = fröhlich bzw. energetisiert

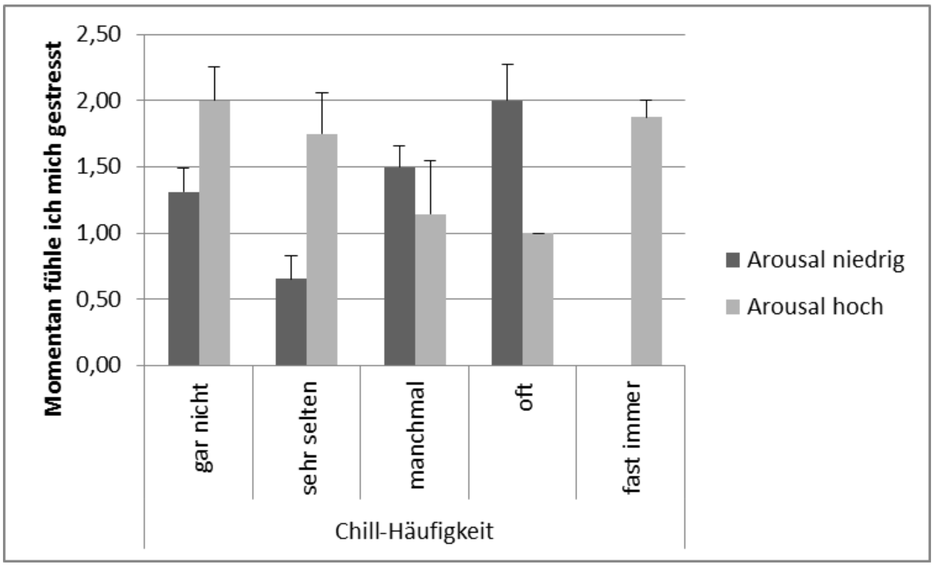
Tabelle 3 Korrelationen zwischen habituellem Chill-Erleben, Musikhören und Stress

Variablen	1	2	3	4	5	6	7	8	9	10	11
1 Chill-Häufigkeit	-										
2 Chill-Intensität	0,533 **	-									
3 Musikhören	0,215 **	0,151 **	-								
4 Valenz	-0,178 **	-0,073	c	-							
5 Arousal	0,189 **	-0,017	c	0,323 **	-						
6 Entspannung	0,396 **	0,110 *	c	-0,123 *	-0,174 **	-					
7 Aktivierung	-0,204 **	0,191 **	c	0,170 **	0,180 **	-0,543 **	-				
8 Ablenkung	0,142 **	0,338 **	c	-0,056	0,187 **	-0,252 **	-0,278 **	-			
9 Gegen Langeweile	-0,086	-0,040	c	-0,180 **	0,047	-0,234 **	-0,121 *	0,161 **	-		
10 Subjektives Stresserleben	0,002	0,000	-0,008	0,056	0,151 **	-0,073	-0,084	0,286 **	-0,037	-	
11 Cortisol	-0,020	0,041	0,042	0,085	-0,021	-0,214 **	0,131 *	0,080	0,103 *	0,079 **	-
12 Alpha-Amylase	-0,127 **	0,060 *	0,103 **	0,170 **	0,009	0,061	-0,027	0,028	-0,056	0,120 **	-0,072 **

Anmerkungen: **Signifikanzniveau p < 0,01 (zweiseitig). *Signifikanzniveau p < 0,05 (zweiseitig); [c] Kann nicht berechnet werden, da mindestens eine der Variablen konstant ist

Es zeigte sich, dass das subjektive Stresserleben in Abhängigkeit von der Häufigkeit des Chill-Erlebens ($\underline{UC}$ = 0,50, $\underline{t}$(348) = 1,801, $\underline{p}$ = 0,073), des Arousals der gehörten Musik ($\underline{UC}$ = 0,01, $\underline{t}$(348) = 3,185, $\underline{p}$ = 0,002), sowie der Interaktion aus Häufigkeit des Chill-Erlebens und Arousal der gehörten Musik ($\underline{UC}$ = −0,01, $\underline{t}$(348) = −2,960, $\underline{p}$ = 0,003) variierte: Dabei zeigte sich, dass das subjektive Stresserleben am niedrigsten ausfiel, wenn Personen, die selten oder gar nicht Chills erleben, Musik mit einem niedrigen Arousal hörten. Hingegen war das subjektive Stresserleben am höchsten, wenn Musik mit einem niedrigen Arousal von Personen, die oft Chills erleben, gehört wurde (Abbildung 2). Dabei konnten 3,29% der Varianz in subjektiven Stress durch die Interaktion aus Chill-Häufigkeit und Arousal der gehörten Musik erklärt werden ($\underline{\chi}^2$ = 32,99, df = 8, $\underline{p}$ < 0,001). Bezüglich der Intensität des Chill-Erlebens zeigten sich keine signifikanten Interaktionseffekte ($\underline{UC}$ = −0,01, $\underline{t}$(293) = −1,694, $\underline{p}$ = 0,091). Bezüglich der biologischen Stressparameter zeigten sich keine Zusammenhänge zwischen Chill-Häufigkeit, Valenz und Arousal ($\underline{UC}$ < 0,01, $\underline{t}$(348) < 0,543, $\underline{p}$ > 0,588), ebenso zeigten sich keine Zusammenhänge zwischen Chill-Intensität, Valenz, Arousal und biologischen Stressmarkern ($\underline{UC}$ < −0,01, $\underline{t}$(293) = −0,432, $\underline{p}$ = 0,666).

<u>Abbildung 2</u> Subjektives Stresserleben in Abhängigkeit der Chill-Häufigkeit und dem eingeschätzten Arousal der gehörten Musik

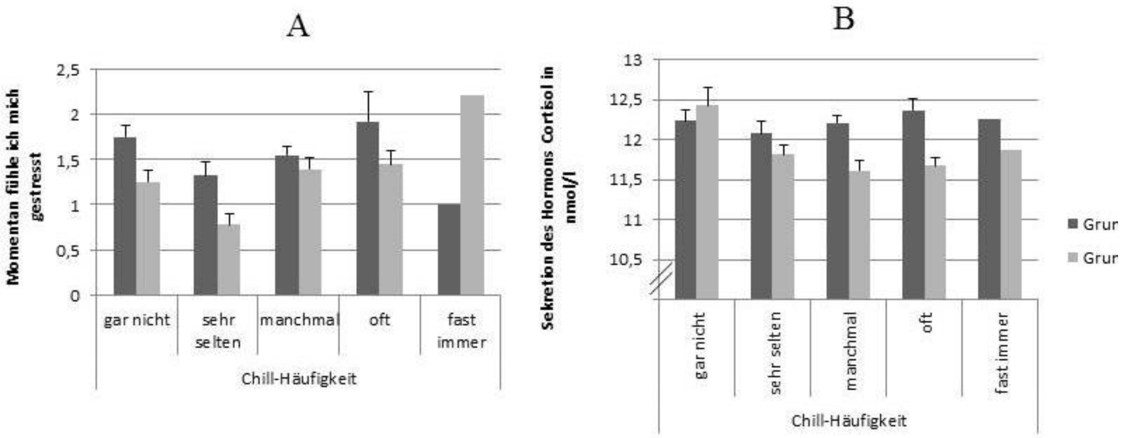


Anmerkungen: Zu Illustrationszwecken wurde die intervallskalierte Variable ‚Arousal' wie folgt aufgeteilt: Arousal niedrig = alle Werte, die mindestens 1 Standardabweichung unter dem Mittelwert der Skala liegen; Arousal hoch = alle Werte, die mindestens 1 Standardabweichung über dem Mittelwert der Skala liegen; Als Fehlerbalken ist der Standardfehler des Mittelwertes abgebildet

3.2 Hypothese 3: Das Erleben von Chills geht in Abhängigkeit von den Gründen des Musikhörens mit einer größeren Stressreduktion durch Musikhören bei chronischen Schmerzpatientinnen einher.

Unter Berücksichtigung der Häufigkeit des Chill-Erlebens zeigte sich, dass in der Gesamtstichprobe Musik, die aus dem Grund Entspannung gehört wurde, mit einem niedrigeren subjektiven Stresserleben einherging ($\underline{UC} = -0,48$, $\underline{t}(350) = -2,975$, $\underline{p} = 0,003$). Dabei konnten 1,21 % der Varianz im subjektiven Stresserleben durch den Musikhörgrund Entspannung erklärt werden ($\underline{\chi^2} = 32.94$, df = 6, $\underline{p} < 0,001$). Zudem zeigte sich eine signifikante Interaktion aus dem Grund der Entspannung und Chill-Häufigkeit ($\underline{UC} = 0,20$, $\underline{t}(350) = 2,148$, $\underline{p} = 0,032$) dahingehend, dass mit zunehmender Häufigkeit des habituellen Chill-Erlebens die stressreduzierende Wirkung von Musikhören aus dem Grund Entspannung abnahm (Abbildung 3A). Dabei wird 0,60% der Varianz in subjektivem Stresserleben durch die Interaktion aus dem Grund Entspannung und der Häufigkeit des Chill-Erlebens erklärt ($\underline{\chi^2} = 24,16$, df = 6, $\underline{p} < 0,001$). Bezüglich der Sekretion des Hormons sCort als AV zeigte sich ebenfalls eine signifikante Interaktion aus Musikhören aus dem Grund Entspannung und der Häufigkeit des Chill-Erlebens ($\underline{UC} = -0,18$, $\underline{t}(350) = -2,522$, $\underline{p} = 0,012$): Die Probandinnen, die angaben, habituell Chills zu erleben, zeigten die geringste Sekretion des Hormons sCort, wenn Musik aus dem Grund Entspannung gehört wurde (Abbildung 3B). Dabei werden 0,89% der Varianz in der Sekretion des Hormons sCort durch die Interaktion aus Entspannung und Häufigkeit des Chill-Erlebens erklärt ($\underline{\chi^2} = 38,17$, df = 7, $\underline{p} < 0,001$). Bezüglich der Aktivität des Enzyms sAA zeigten sich keine Effekte der Interaktion ($\underline{UC} = 0,03$, $\underline{t}(350) = 0,271$, $\underline{p} = 0,787$). Auch hinsichtlich der Intensität des Chill-Erlebens ergaben sich keine signifikanten Interaktionen ($\underline{UC} < -0,10$, $t(195) \leq -1,038$, $\underline{p} > 0,300$).

Abbildung 3 Der Zusammenhang zwischen der Häufigkeit des Chill-Erlebens und dem Grund ‚Entspannung' hinsichtlich des subjektiven Stresserlebens (A) und hinsichtlich der Sekretion des Hormons sCort (B)



4. Diskussion

4.1. Zusammenfassung der Ergebnisse

Die Häufigkeit des habituellen Chill-Erlebens war nicht mit Stressparametern assoziiert. Allerdings zeigte sich, dass eine höhere habituelle Intensität des Chill-Erlebens mit einer höheren Aktivität des Enzyms sAA nach dem Musikhören einherging. Die Effekte des Musikhörens auf das Stresserleben wurden beeinflusst von der Interaktion aus Häufigkeit des Chill-Erlebens, dem wahrgenommenen Arousal der gehörten Musik sowie von der Interaktion aus Häufigkeit des Chill-Erlebens mit den Gründen des Musikhörens: Das subjektive Stresserleben wurde am niedrigsten eingeschätzt, wenn Personen, die gar nicht oder selten Chills erleben, Musik mit einem niedrigen wahrgenommenen Arousal hörten. Hingegen war das subjektive Stresserleben bei Personen, die oft Chills erleben, am geringsten, wenn diese Musik hörten, die ein hohes wahrgenommenes Arousal hatte. Die wahrgenommene Valenz der Musik spielte keine Rolle. Bezüglich der Gründe des Musikhörens zeigte sich, dass mit zunehmender Häufigkeit des habituellen Chill-Erlebens die stressreduzierende Wirkung von Musikhören aus dem Grund Entspannung abnahm. Entgegengesetzt verhielt es sich mit der Sekretion des Hormons sCort: Diese war am geringsten bei Personen, die habituell Chills erleben und Musik aus dem Grund Entspannung gehört haben.

4.2. Das Erleben von Chills beeinflusst die stressreduzierende Wirkung von Musikhören im Alltag

Die Effekte bloßen Musikhörens auf Stressparameter unterschieden sich in Abhängigkeit von der Intensität des habituell berichteten Chill-Erlebens dahingehend, dass Personen, die zu intensiverem Chill-Erleben neigen, eine erhöhte Aktivität des ANS (gemessen anhand der Aktivität des Enzyms sAA) nach dem Hören von Musik erlebten. Vor dem Hintergrund, dass die Aktivität des ANS (in der Regel gemessen anhand der elektrodermalen Aktivität) als ein physiologisches Korrelat von Chill-Erleben gilt, ist es interessant, dass gerade Personen, die zu intensiverem Chill-Erleben neigen, aktivierende Effekte beim bloßen Musikhören im Alltag erleben. Während intensiven Chill-Erlebens zeigt sich ebenfalls eine erhöhte Aktivität des ANS in anderen Studien (Benedek & Kaernbach, 2011; Grewe, et al., 2009; Grewe, et al., 2007). Der Befund, dass das bloße Musikhören bei Personen mit habituell höherer Chill-Intensität aktivierende Effekte hat, könnte darauf hindeuten, dass Personen, die zu intensivem Chill-Erleben neigen, schneller mit Aktivierung auf Musik reagieren. Zu dieser Interpretation passt der Befund, dass vor allem die Patientinnen, die häufig und intensiv Chills erleben, seltener angaben, Musik speziell aus dem Grund Aktivierung zu hören. Somit hat Musikhören per se bei Personen, die häufig und intensiv Chills erleben, aktivierende Effekte (unabhängig vom Grund des Musikhörens). Gleichzeitig gaben die Personen, die häufig Chills erleben, aber auch in dieser Studie an, dass sie im Durchschnitt Musik mit einem höheren Arousal gehört hatten. So könnte die Präferenz für Musik mit einem höheren Arousal auch erklären, warum Personen mit habituell häufigerem und intensiverem Chill-Erleben mit Aktivierung auf Musik reagieren.

4.3. Die Rolle der Valenz und des Arousals der gehörten Musik

Die Effekte des Musikhörens auf das Stresserleben variierten in Abhängigkeit von dem Arousal der gehörten Musik. Dabei scheint ein hohes Arousal der gehörten Musik bei Personen, die häufig Chills erleben, das Stresserleben zu erhöhen. Im Folgeschluss würde es bedeuten, dass Personen, die selten Chills erleben, am besten von Musik mit einem geringen Arousal zur Stressreduktion profitieren. Dies steht im Einklang zu bisherigen Befunden, die zeigen, dass Musik mit einem niedrigen Arousal die stressreduzierende Wirkung von Musikhören fördert (Chanda & Levitin, 2013). Dieser Zusammenhang scheint aber nicht universell zu gelten, denn bei Personen, die häufig Chills erleben, konnten wir in dieser Studie eher aktivierende Effekte der Musik beobachten. Zudem gaben genau diese Personen auch häufiger an, Musik mit einem hohen Arousal zu hören. Somit scheint das Arousal der gehörten Musik kein Prädiktor für eine Stressreduktion durch Musik bei Personen zu sein, die häufig Chills erleben. Folglich stellt die

Häufigkeit des habituellen Chill-Erlebens einen wichtigen Moderator in diesem Kontext dar, der berücksichtigt werden sollte, wenn Musik zu Stressreduktionszwecken eingesetzt wird.

Dass Personen, die habituell häufiger und intensiver Chills erleben, eher aktivierende Musik hören, ist vor dem Hintergrund lerntheoretischer Annahmen sowie neurobiologischer Befunde zum Chill-Erleben ein interessanter Befund. Da Chills als vornehmlich positive Erlebnisse wahrgenommen werden (Panksepp, 1995) und neben Aktivierungen des ANS auch mit einer Aktivierung in den Belohnungszentren des Gehirns einhergehen (Blood & Zatorre, 2001), liegt die Vermutung nahe, dass Personen Musik präferieren, die Chills auslöst, um diesen positiven Zustand zu erreichen. In der Literatur werden die Valenz der Musik (Panksepp, 1995) sowie psychoakustische Merkmale wie Lautstärke und Tempo (Grewe, et al., 2007) mit dem Auftreten von Chills in Verbindung gebracht. In dieser Studie zeigten sich allerdings keine Unterschiede in der stressreduzierenden Wirkung von Musik in Abhängigkeit von der wahrgenommenen Valenz der gehörten Musik. Stattdessen zeigten sich Unterschiede in Abhängigkeit von dem wahrgenommenen Arousal der gehörten Musik. Demnach scheint Musik mit einem hohen Arousal für Personen, die habituell häufiger und intensiver Chills erleben, eher positiv konnotiert zu sein. Dies könnte darauf hindeuten, dass vor allem dem Arousal (und weniger der Valenz) eine besondere Bedeutung zukommen sollte, wenn es darum geht, welche musikalischen Stimuli Chills auslösen.

4.4. Die Rolle der Gründe des Musikhörens

Während das Arousal der gehörten Musik eher aktivierende Effekte des Musikhörens bei Personen, die häufig Chills erleben, ausübt, zeigt sich in Abhängigkeit von den Gründen des Musikhörens ein anderes Bild: Personen, die häufig Chills erleben und Musik aus dem Grund Entspannung gehört haben, zeigten höhere subjektive Stresswerte und zeitgleich eine geringere Sekretion von sCort. Dies scheint auf den ersten Blick widersprüchlich, ist aber durchaus vereinbar: Probandinnen, die häufiger Chills erleben, gaben in dieser Studie auch an, dass sie häufiger Musik aus dem Grund Entspannung hören als Probandinnen, die seltener Chills erleben. Aus lerntheoretischer Sicht könnte dies bedeuten, dass Personen, die häufiger Chills erleben, mehr positive Erfahrungen mit Musikhören aus dem Grund Entspannung gemacht haben, und daher Musik häufiger zur Entspannung hören. Weiter könnten sich Personen mit unterschiedlicher Lernerfahrung bezüglich des Erfolgs von Musikhören aus dem Grund Entspannung durch mehr unterscheiden, als nur durch die Häufigkeit ihrer Versuche, Stress durch Musik zu regulieren: Sie könnten sich z.B. auch darin unterscheiden, bis zu welchem Stresslevel sie Musik erfolgreich zur Stressreduktion einzusetzen vermögen. Es könnte sein, dass diese Personen Musik auch einsetzen, wenn sie einem größeren Ausmaß an Stress ausgesetzt sind, und dass sie damit auch eine Stressreduktion erreichen. Falls sich das Ausgangsniveau im Stresserleben vor Beginn des Musikkonsums zwischen Personen mit und ohne habituellem Chill-Erleben unterscheiden sollte, wären deren Angaben bezüglich subjektivem Stresserleben nach Musikkonsum nicht mehr für sich alleinstehend zwischen den beiden Gruppen vergleichbar. Das Ergebnis, dass Probandinnen mit häufigerem Chill-Erleben nach Musikhören aus dem Grund Entspannung subjektiv gestresster waren, ließe sich so betrachtet dadurch erklären, dass sie vor dem Musikhören durchschnittlich gestresster waren als Personen mit seltenerem Chill-Erleben. Sie könnten sehr wohl eine Stressreduktion durch Musik erfahren haben, was sich physiologisch anhand der Sekretion des Hormons sCort zeigt, sich aber subjektiv gemessen nicht als Gruppenunterschied im Sinne einer erfolgreichen Stressreduktion bei Personen mit habituellem Chill-Erleben niederschlägt, da die Personen, die seltener Chills erleben, eventuell nur dann Musik hörten, wenn sie weniger gestresst waren, und so mit einem niedrigeren subjektivem Stresserleben vor dem Musikkonsum starteten. Dies stellt einen wichtigen Befund dar, da sich bislang sowohl bei Gesunden zu Zeiten erhöhten Stresses als auch bei chronisch gestressten Patientinnen im Alltag kein stressreduzierender Effekt von Musik gezeigt hat (Linnemann, Ditzen, et al., 2015; Linnemann, Kappert, et al., 2015). Die Befunde dieser Studie deuten nun darauf hin, dass Personen, die habituell Chills erleben, Musik unter erschwerten Bedingungen, d.h. wenn ein größeres Stresserleben empfunden wird, erfolgreicher zur Emotionsregulation einsetzen könnten. Zeitgleich deuten die Befunde darauf hin, dass sich Personen, die häufiger und intensiver Chills erleben, nicht nur hinsichtlich der Musikauswahl unterscheiden, sondern auch hinsichtlich der Situationen, in denen sie Musik hören. Dieser Befund sollte bestehende Modellvorstellungen zum Erleben von Chills (Grewe, et al., 2007) spezifizierend ergänzen.

4.5 Begrenzungen

Zwar ist dies die erste Studie, die die Effekte des Musikhörens im Alltag in Abhängigkeit des habituellen Chill-Erlebens untersucht, allerdings sind dabei einige Limitationen kritisch zu diskutieren: Zum einen erfolgte die Erfassung von Musikhören und Stresserleben zeitversetzt, so dass theoretisch bis zu vier Stunden zwischen Musikhören und Erhebung der Stressparameter liegen konnten. Hier wäre es sinnvoll, zukünftig durch event-basierte Messungen eine höhere zeitliche Auflösung von Musikhören und Stresserleben zu gewährleisten. Gerade vor dem Hintergrund, dass sCort und sAA unterschiedliche zeitliche Reaktionsmuster aufweisen, könnten durch eine höhere zeitliche Auflösung differenzierte Aussagen über akute Effekte des Musikhörens auf das Stresserleben getätigt werden. Auch könnte man so direkt erfassen, wie hoch das Stresserleben unmittelbar vor und nach dem Musikhören ausfällt. So wären Aussagen darüber möglich, ob Personen, die habituell Chills erleben, auch wirklich Musik bei höherem Stresserleben einsetzen. Zudem ist kritisch anzumerken, dass die Angaben bezüglich des habituellen Chill-Erlebens auf Selbstbericht beruhen. Ob die Probandinnen, die angaben, habituell häufiger und intensiver Chills zu erleben, dies auch wirklich getan haben, konnten wir nicht kontrollieren. Zukünftige Studien sollten zusätzlich zu diesen generellen Angaben erfassen, wann genau Chills im Alltag erlebt wurden. Auch basiert die Einschätzung der Valenz und des Arousals der Musik auf dem subjektiven Selbstbericht, so dass keine objektiven Aussagen darüber möglich sind, ob sich Personen in Abhängigkeit vom habituellen Chill-Erleben auch in der Auswahl der Musik objektiv unterscheiden. Dies sollte in zukünftigen Studien untersucht werden, indem in Ergänzung zu den subjektiven Angaben hinsichtlich des Musikhörverhaltens die Musik, die die Proband/innen hören, ebenfalls kontinuierlich objektiv erfasst wird. Auch ist die Stichprobengröße kritisch zu betrachten. Da sich die Stichprobengröße durch die Zahl der Non-Responder von N = 30 auf N = 22 verkleinert hat, hat sich somit auch die Teststärke verringert. Gerade vor dem Hintergrund der allgemein eher kleinen Effektstärken in Alltagsstudien ist es wichtig, die Ergebnisse an einer größeren Stichprobe zu replizieren. Durch die Untersuchung von ausschließlich weiblichen FMS-Patientinnen ist keine Generalisierung der Befunde auf männliche Probanden möglich. Auch können die Befunde nicht auf gesunde Proband/innen übertragen werden, da Patient/innen mit FMS häufig Veränderungen in der Aktivität des ANS und der HHNA aufweisen (Martinez-Lavin, 2002; Tak et al., 2011). Studien an gesunden Proband/innen in unterschiedlich stressigen Alltagssituationen sind also notwendig, um zu überprüfen, ob die hier gefundenen Zusammenhänge zwischen Chills, Musikhören und Stress auch auf gesunde Proband/innen übertragbar sind.

4.6 Schlussfolgerung

Die stressreduzierende Wirkung von Musikhören im Alltag variiert in Abhängigkeit des habituellen Chill-Erlebens. Dabei scheinen Personen, die häufig und intensiver Chills erleben, im Vergleich zu Personen, die seltener und weniger intensiv Chills erleben, vor allem mit einer größeren Aktivierung auf Musikhören zu reagieren. Musik an sich ist somit nicht zu Stressreduktionszwecken bei Personen mit häufigerem und intensiverem habituellen Chill-Erleben geeignet. Wird Musik allerdings aus dem Grund Entspannung gehört, so zeigt sich ein stressreduzierender Effekt. Folglich benötigen Personen, die häufig und intensiv Chills erleben, andere Musik im Alltag, um eine Stressreduktion zu erreichen. Somit stellt die habituelle Komponente des Chill-Erlebens eine wichtige Moderatorvariable im Kontext von Musik und Stress dar.

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Appendix B: Summary

Stress stellt eine Gefahr für die Gesundheit dar. Vor allem das hohe Ausmaß an berichtetem Stress im Alltag, macht die Erforschung von stressreduzierenden Maßnahmen, die direkt im Alltag angewandt werden können, notwendig. Das Hören von Musik im Alltag kann eine dieser Maßnahmen darstellen. Musikhören ist eine beliebte Aktivität des Alltags, die leicht verfügbar und kostengünstig ist. Zudem konnte Musikhören in einer Reihe experimenteller Studien bereits mit gesundheitsförderlichen Effekten in Verbindung gebracht werden. Dabei wird diskutiert, dass Musikhören diese positiven Effekte durch eine Reduktion im psychobiologischen Stress auslöst. Allerdings sind diesbezüglich folgende Fragen noch ungeklärt:

1. Sind Effekte aus experimentellen Labor-Studien auf den Alltag übertragbar?
2. Was genau an Musik wirkt stressreduzierend?
3. Welche psychobiologischen Mechanismen unterliegen diesem Effekt?

Ziel der vorliegenden Dissertation war es daher, einen potenziellen stressreduzierenden Effekt von Musikhören im Alltag näher zu untersuchen. Dabei war es vor allem wichtig zu identifizieren, wodurch Musikhören genau stressreduzierend wirkt und psychobiologische Mechanismen zu identifizieren, die diesem stressreduzierenden Effekt zu Grunde liegen. Basierend auf bisheriger Literatur wurde ein Rahmenmodell postuliert, welches einen gesundheitsförderlichen Effekt von Musikhören durch eine Reduktion im psychobiologischen Stress (hier operationalisiert anhand subjektivem Stresserleben, Sekretion des Hormons Cortisol und Aktivität des Enzyms Alpha-Amylase) erklärt. Dabei wurden Charakteristika der Musik, der Person und der Situation in ihrem Anteil an diesem förderlichen Effekt von Musik untersucht, was Gegenstand von sechs Publikationen war.

Zunächst wurde anhand einer methodologischen Publikation ein Studienprotokoll für die Erfassung von Effekten von Musikhören auf psychobiologischen Stress im Alltag etabliert, da die begrenzte Anzahl an Alltagsstudien zu den positiven Effekten von Musik ausschließlich auf subjektiven Selbstberichten beruht. Die nachfolgenden Publikationen basieren auf diesem Studienprotokoll.

In der zweiten Publikation wurden die Effekte von Musikhören auf psychobiologischen Stress im Alltag von Gesunden untersucht. Dabei erwiesen sich vor allem Charakteristika der Situation sowie Charakteristika der Musik als prädiktiv für den stressreduzierenden

Effekt von Musikhören. Zudem wurden psychobiologische Stressmarker differentiell von Musikhören dahingehend beeinflusst, dass die Gründe des Musikhörens mit der Sekretion des Hormons Cortisol und das Arousal der Musik mit der Aktivität des Enzyms Alpha-Amylase assoziiert waren. Zudem variierte der stressreduzierende Effekt in Abhängigkeit des Ausmaßes an berichtetem Stress dahingehend, dass Musikhören nicht in einer Phase erhöhten Stresses zu einer Stressreduktion führte.

In der dritten Publikation wurden Charakteristika der Situation näher hinsichtlich des stressreduzierenden Effektes untersucht. Dabei stand vor allem die Anwesenheit anderer Personen beim Musikhören im Fokus. Es zeigte sich, dass der stressreduzierende Effekt von Musikhören in der Anwesenheit anderer Personen variierte. Somit wurde der stressreduzierende Effekt von Musik hinsichtlich des subjektiven Stresserlebens sowie hinsichtlich der Sekretion des Hormons Cortisol verstärkt, während Musikhören in der Anwesenheit anderer Personen die Aktivität des Enzyms Alpha-Amylase steigerte.

Auf diesen Resultaten aufbauend, wurden in der vierten Publikation soziale Charakteristika der Situation näher untersucht, in dem Paare in ihrem Alltag Angaben zu Musikhören, Interaktionsverhalten und Stresserleben tätigten. Es zeigte sich, dass Musikhören sowohl das Interaktionsverhalten als auch das Stresserleben beeinflusste. So gaben Frauen häufiger nach dem Hören von Musik an, dass sie Kontakt zu ihrem Partner hatten. Hörte allerdings der Partner Musik, schätzen die Frauen den Kontakt negativer ein. Zudem zeigte sich, dass vor allem Frauen von Musikhören im Alltag zur Stressreduktion profitierten, während Männer eher mit einer Aktivierung auf Musik reagierten. Auch ergaben sich 'cross-over' Effekte dahingehend, dass sich der Effekt der Musik bei dem einen Partner auf den anderen Partner übertrug.

In der fünften und sechsten Publikation wurde untersucht, inwiefern der schmerzreduzierende Effekt von Musikhören durch eine psychobiologische Stressreduktion bei Patientinnen mit Fibromyalgie-Syndrom vermittelt wurde. Es zeigte sich, dass Musikhören die Kontrolle über Schmerzen verbesserte. Allerdings wurde dieser Effekt nicht durch eine Stressreduktion vermittelt. In einer anschließenden Analyse wurde untersucht, ob ein potenzieller stressreduzierender Effekt bei Patientinnen mit Fibromyalgie-Syndrom durch differentielle Persönlichkeitsunterschiede erklärt werden kann. Dabei zeigte sich, dass die Fähigkeit musik-induzierte Chills zu erleben, den stressreduzierenden Effekt von Musikhören beeinflusste.

Die Resultate der Studien zeigen, dass verschiedene Charakteristika der Musik (z.B. Arousal), der Situation (z.B. Anwesenheit anderer Personen beim Musikhören) und der Person (z.B. habituelles Chill-Erleben) den stressreduzierenden Effekt von Musikhören im Alltag beeinflussen. Dabei werden psychobiologische Stressmarker differentiell vom Musikhören beeinflusst. Die Aktivität von Alpha-Amylase ist mit Charakteristika der Musik assozi-

iert, während die Sekretion von Cortisol durch Gründe des Musikhörens beeinflusst wird. Somit zeigt sich eine Parallelität zwischen den kognitiven Verarbeitungsprozessen von Musik und den Reaktionsmustern von stress-sensitiven Systemen im Körper. Während Musik zunächst akustisch im Gehirn analysiert wird und somit unmittelbar das autonome Nervensystem beeinflusst, werden erst später emotionale Verarbeitungsprozesse ausgelöst, die dann zeitversetzt das limbische System erreichen und von hier die Hypothalamus-Hypophysen-Nebennierenrinden Achse beeinflussen. Des Weiteren interagieren Charakteristika der Musik, der Situation und der Person miteinander. Somit zeigt sich der stressreduzierende Effekt von Musikhören inter- und intraindividuell variabel, was die Konzeption von Musikinterventionen zur Stressreduktion prägend beeinflussen kann. Insgesamt kann Musikhören im Alltag als Mittel der Stressreduktion eingesetzt werden. Dabei sollten die komplexen Interaktionen aus Charakteristika der Musik, der Situation und der Person hinsichtlich der differentiellen Wirkung auf stress-sensitive Systeme des Körpers berücksichtigt werden, um ein optimales Wirkungsmuster gewährleisten zu können.

Appendix C: Eidesstattliche Erklärung

Ich versichere, dass ich meine Dissertation

Psychobiological mechanisms underlying the stress-reducing effects of music listening in daily life

selbstständig und ohne unerlaubte Hilfe angefertigt und mich dabei keiner anderen als der von mir ausdrücklich bezeichneten Quellen und Hilfen bedient habe. Die Dissertation wurde in der jetzigen oder einer ähnlichen Form noch bei keiner anderen Hochschule eingereicht und hat noch keinen sonstigen Prüfungszwecken gedient.

Marburg, 13. Juni 2016

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