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Study Protocol: Investigating the Effects of Historical Idiophones on Psychological and Physiological Stress

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Abstract

Given the severe effects of stress on both long-term and short-term physical and mental health, exploring stimuli that either induce or alleviate stress has garnered significant attention. Historical evidence suggests that stress and its reduction were important concerns even in past civilisations, prompting curiosity about the methods people used to manage stress. This study, as part of the project “Metallic Idiophones in Central Europe between 800 AD and 800 BC” (Pomberger et al., 2021a), delves into the historical significance of metallic idiophones, positing that these instruments might have been worn for their sound’s effects on humans themselves, specifically on stress. The project investigates excavated idiophones through interdisciplinary approaches, encompassing archaeology, acoustics, and psychology, to understand their cultural motivations and effects. The current empirical research within this project includes two studies using a randomized controlled design to explore the stress-altering effects of historical idiophones. The first study examines the stress-reducing effects of a low-arousal pellet-bell following a stressor (cold pressor test). The second study explores the stress-inducing effects of a high-arousal pellet-bell following relaxation (nature sounds). Stress is assessed through hormonal, cardiovascular, and subjective measurements. This dual approach aims not only to shed light on the cultural motivations behind the use of metallic idiophones in past societies but also to contribute valuable insights into their potential stress-modulating role. By attempting to replicate the ancient use of bells and pellet-bells for stress reduction, this research seeks to determine whether these auditory stimuli have inherent stress-relieving effects, independent of their historical context.

Keywords: stress, musicology, archaeology, psychology, psychoacoustics, cold pressor test

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1. Introduction

Stress represents a fundamental physiological and psychological response to perceived threats or challenges (McEwen, 2007). While stress is a normal response to a stressor, chronic stress and maladapted stress responses have been associated with significant health risks and are implicated in the development of numerous physiological and psychological disorders (McEwen, 2007; Shields & Slavich, 2017). Stress has for instance been linked to depression (Slavich & Irwin, 2014), schizophrenia (Feigenson et al., 2014) and bipolar disorder (Myin-Germeys et al.; 2003) as well as cardiovascular disease (Strike & Steptoe, 2003; Dimsdale, 2008), autoimmune disorders (Silverman & Sternberg, 2012) and Alzheimer's disease (Akiyama et al., 2000). Due to the severity of maladapted stress responses on health, research has long been interested in interventions that may reduce stress. A range of stress-reducing practices and treatments have been explored, including physical activities such as yoga and Tai Chi (Kong et al., 2019; Chong et al., 2011; Asmundson et al., 2013), meditation and mindfulness practices (Song & Lindquist, 2015), and classical cognitive behavioural therapy (Arch et al., 2013). One lesser-researched potential stress-reducing factor is music and auditory stimuli in general. Some studies have found that auditory stimuli like music can help recover heart rate (de la Torre-Luque, 2017), lower blood pressure (Chafin et al., 2004), reduce anxiety (Gan et al., 2016), and improve mood (Koelsch et al., 2016). However, notably other studies have found no similar effects (Fallon et al., 2020; Labbé et al., 2007; Radstaak et al., 2014; Sokhadze, 2007). Some studies have looked more specifically on music listening and practicing as a means for stress reduction. For instance, Grebosz-Haring et al. (2022) have found significant reductions in salivary cortisol after choir singing. Additionally, Wuttke-Linnemann et al. (2019) showed that listening to music reduced stress biomarkers in both women and men, but in different ways, painting a more complex picture of the influence of music on stress. A study by Linnemann et al. (2018) investigated music listening in a more ecologically valid setting in an Ambulatory Assessment study, which found a negative relationship with subjective stress and music listening but did not find the same results for objective data. These results show the complex and diverse ways in which music and auditory stimuli can affect stress. Given that auditory stimuli are inexpensive and widely available, they present a promising area for stress reduction and therefore warrant further research.

The current project, consisting of two studies, is a pioneering interdisciplinary effort. It lies at the intersection of clinical psychology, with its focus on stress; systematic musicology, with its interest in the influence of auditory stimuli on humans; and archaeology, with its interest in the use of historical artifacts—in this case, idiophones—in a historical setting. The current study primarily focuses on investigating the historical significance of metallic idiophones in past cultures, with a secondary aim of furthering knowledge on the influence of auditory stimuli on stress.

Before delving into the intersection of historical sound artifacts and stress research, it is essential to establish an understanding of each involved component. Thus, the following sections will introduce historical idiophones, discuss the evolution of stress and stress research, outline the physiology and measurement of stress, and finally, present the research question and aims of the current study.

1.1. Historical Idiophones

As defined by Hornbostel and Sachs (1914) idiophone refers to musical instruments that create sound by the instrument's vibrating body, without strings, membranes or other external resonators. One common idiophone, often used in cultural or ritual context, are pellet-bells. They are constructed with a hollow body with a loose pellet inside. Through movement of the pellet-bells the pellet inside hits the interior wall, creating sounds. A defining aspect of pellet-bells is, that they are not casted like bells, but rather hammered from sheets of metal. Their sound is defined by their size, material und pellet (Blades & Holland, 1992).

While today's use for idiophones is focused on producing music, this differs from their historic use. Various historical sources indicate that these idiophones were worn by people on their garments, either loosely hanging or in pouches (Pomberger et al., 2021b). Yet, there is little evidence on why they have been worn. Some theories pose, they were worn as accessories, for apotropaic reasons, as deterrent to wild animals or for potential psychological reasons such as the effects of their sounds on people (Pomberger et al., 2021a, Pomberger 2023). The latter was first investigated by Pomberger et al. (in press). In this study a broad range of sounds from original excavated and historically accurate replicated idiophones, such as bells, pellet-bells and fibulae, have been rated by participants according to their psychoacoustic properties.

While this study found an array of significant results, interestingly the idiophones' sounds were rated vastly different in their perceived arousal. As arousal of stimuli plays a key role in stress induction or relaxation (Lazarus, 1966), these results further the interest in stress reducing effects of idiophones and auditory stimuli in general. To address the significant differences in the arousal ratings of various idiophones, the current study will include two idiophones of similar build but with vastly different arousal ratings. These differences have been attributed to their construction materials, which affect their sound frequency spectrum (Pomberger et al., in press). Consequently, these distinct idiophones may have been worn for different reasons.

1.2. Stress Across History

As this novel research interest puts stress research in a historical context, understanding the history of stress and stress research itself is important. In scientific research, the concept of stress has a relatively recent history, dating back to the first publication by Hans Selye, often regarded as the "forefather" of stress research (Hutmacher, 2021; Lu et al., 2021). Although earlier works by George M. Beard (1869) and Walter B. Cannon (1929) preceded Selye's seminal work on the general adaptation syndrome (Selye, 1939), Selye's contributions are generally considered the foundational starting point for the now extensive body of research on stress (McCarty, 2020). Yet, the general concept of stress seems to predate Selye's work on stress (Selye, 1939), Cannon's work on homeostasis (Cannon, 1929) or even Claude Bernard's work on equilibrium (Bernard, 1878). The concept can already be found in texts of Greek philosophers such as Heraclitus, Empedocles, Hippocrates or Epicurus, wherein they contemplate problems of keeping harmony, equilibrium and balance within living organisms as a means to survive (Le Moal, 2007). Moreover, biological evidence indicates that stress has likely been a fundamental aspect of human experience throughout history. For instance, by analysing the fingernail of the mummified body now known as "Ötzi," which dates back over 5000 years, Capasso (1994) identified distinct periods of stress in the final months of Ötzi's life. While the herein used methodology of analysing Beau's Lines as indicators of stress may be disputed (Agouridis et al., 2024), the finding that stress dates back to older civilizations is supported by Webb et al. (2010). They analysed hair-sample cortisol from humans dating back as early as 1500 years ago, showing measurable cortisol levels in all the individuals studied.

This indicates that stress has been a pervasive aspect of human experience throughout history. While there is research on the changes in the prevalence of stress over time, making conclusive statements is challenging. Some studies suggest a steady increase in stress in recent history (Butterworth et al., 2020, Mahmud et al., 2021). However, these findings are significantly hindered by frequent changes in diagnostic criteria and materials, which vary not only across different time periods but also between locations (Harvey et al., 2017), making reliable longitudinal conclusions difficult. Furthermore, there is sparse data available dating back more than 20 years. One emerging methodology that attempts to circumvent these limitations comes from the field of computational social sciences (Muñoz and Iglesias, 2022). Using lexical-based feature analysis, researchers investigate the prevalence of stress over time within large datasets sourced from written media such as literature, social media, or news articles (Bandhakavi et al., 2017; Banerjee & Shaikh, 2021; Cao et al., 2021; Winata et al., 2018). Research in this field suggests that stress has fluctuated across history, predating modern diagnostic material. Combining this evidence with the enduring engagement with stress, a picture emerges of stress as a timeless phenomenon. This highlights the importance of this new perspective in stress research, which puts it into a historical context.

1.3. Physiology and Measurement of Stress

To understand stress reducing or inducing interventions, it is fundamental to first understand how the concept of stress manifests itself and how this can be measured. The body's response to stress involves hormonal and neural pathways, primarily through the hypothalamic-pituitary-adrenal (HPA) axis and the autonomic nervous system (ANS). These pathways can be indirectly assessed using physiological and biochemical markers such as cortisol, heart rate (HR), heart rate variability (HRV), electrodermal activity (EDA), and salivary alpha amylase (sAA). In response to stress, the HPA axis triggers the release of corticotropin-releasing hormones from the hypothalamus, stimulating the pituitary gland to release adrenocorticotrophic hormone, which then prompts the adrenal glands to release cortisol (Smith & Vale, 2006). Cortisol, a glucocorticoid hormone, plays a central role in the stress response by mobilizing energy through increasing blood glucose levels and suppressing functions such as immune response and digestion (McEwan, 2007). Elevated cortisol levels are typically observed in blood, saliva, and hair samples from individuals experiencing acute or

chronic stress (Hellhammer et al., 2009). The ANS, comprising the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS), responds to stressors. Activation of the SNS during stress leads to increased heart rate, dilated pupils, reduced digestive functions, and secretion of catecholamines like adrenaline and noradrenaline (Ulrich-Lai & Herman, 2009). Higher SNS activity also results in lower HRV, which refers to the variation in interbeat intervals of successive heartbeats. Higher HRV indicates a relaxed state, whereas lower HRV suggests heightened stress, thus serving as a measure of SNS activity (Shaffer & Ginsberg, 2017). Another biomarker of SNS activity is EDA, also known as galvanic skin response, which measures changes in skin conductance due to sweat gland activity regulated by the SNS. Due to its rapid response to stimuli, EDA serves as an immediate stress biomarker (Rahma et al., 2022). More recently sAA has gained interest as an indirect measurement of ANS activity in stress research (Rohleder et al., 2004; Granger et al., 2007; Ali & Nater, 2020). This enzyme is involved in starch breakdown and has been shown to rapidly increase during acute stress (Nater & Rohleder, 2009; Nater, 2004). While each of these physiological responses is a healthy and necessary part of the stress response, they can have significant health implications if they are disproportionate or become chronic (Suri & Vaidya, 2015).

1.4. Study Aims and Hypotheses

Given the potential of auditory stimuli as stress modulators and the historical context of metallic idiophones, this research addresses a number of open research questions, exploring the effects of high-arousal and low-arousal metallic idiophones on stress. By integrating interdisciplinary insight from clinical psychology, systematic musicology and archaeology, this study aims to elucidate the potential benefits of idiophone use in stress modulation. Additionally, this study seeks to provide further evidence as to the reasons behind the historic use of these idiophones by past civilisations, assuming they may have been worn for their sounds effects on humans. Specifically, the research consists of two distinct studies designed to investigate the effects of low-arousal (Study 1) and high-arousal (Study 2) metallic idiophones on stress.

1.4.1. Study 1

Study 1 is centred on examining the stress-reducing effects of wearing a low-arousal pellet-bell. Previous research suggest that auditory stimuli can have calming and stress-reducing effects (Chafin et al., 2004; Gan et al., 2016; Koelsch et al., 2016). Pellet bells produce distinct sounds that could potentially influence stress response and furthermore help to understand their use in historic civilisation. In this study, participants will be subjected to a standardized stressor, the cold pressor test (CPT), after which they will perform a series of walking pattern while wearing a low-arousal pellet bell or a silent control bell. This walking-paradigm simulates everyday walking movement and serves to elicit sound from the pellet-bell, as would have been the case for their wear in historic use. Physiological and psychological stress will repeatedly be assessed to determine whether the sound produced can facilitate stress-reduction.

For Study 1 we hypothesise that:

- H1: Wearing a pellet-bell with low arousing sound reduces physiological stress after a stressor more, than wearing a pellet bell without sound.
- H2: Wearing a pellet-bell with low arousing sound reduces psychological stress after a stressor more, than wearing a pellet bell without sound.

1.4.2. Study 2

Study 2 shifts focus to potential stress-inducing effects of wearing a high-arousal pellet-bell. Herein subjects will be presented with nature sounds for relaxation as opposed to the stressor in Study 1. They will perform the same walking paradigm as in Study 1, with the key difference being their wearing of a high-arousal pellet-bell.

For Study 2 we hypothesise that:

- H1: Wearing a pellet-bell with high arousing sound increases physiological stress after relaxation more, than wearing a pellet bell without sound.
- H2: Wearing a pellet-bell with high arousing sound increases psychological stress after relaxation more, than wearing a pellet bell without sound.

The significance of these studies lies in their potential to uncover new, non-invasive methods for stress management. If low-arousal sounds from idiophones are found to reduce stress effectively, they could be incorporated into therapeutic practices for individuals experiencing chronic stress. Conversely, understanding the stress-inducing potential of high-arousal sounds could help in developing better coping mechanisms for environments where such stimuli are prevalent.

Through these studies, we aim to bridge the gap between past practices and contemporary stress management strategies, potentially offering innovative solutions for enhancing well-being. Furthermore, the research aims to elucidate whether the historical use of idiophones was influenced by their potential to modulate stress thus providing a deeper understanding of their cultural and functional significance in past civilisations.

2. Methods

2.1. Study Design

The current study is part of the project "Metallic Idiophones between 800 BC and 800 AD in Central Europe" funded by the Austrian Science Funds FWF and supported by the Natural History Museum Vienna (Pomberger, 2021a). This project investigates metallic sound artefacts (idiophones). It uses excavated and replicated idiophones to answer questions of historical, archaeological, acoustical and psychological nature. The ultimate goal is to combine findings from these research fields in order to gain a better understanding of the idiophones use and importance to society.

The current study is a two-part laboratory-based blinded randomized controlled trial with two conditions for each study. Study 1 consists of an experimental condition using a low-arousal copper pellet-bell and a control condition with a silent pellet-bell. Study 2 consists of an experimental condition using a high-arousal iron pellet-bell and the same silent pellet-bell control as in Study 1. Further details about the bells are provided in the Materials and Equipment section. Randomization determines which condition each participant will complete first; half of the participants in each study will start with the experimental condition, and the other half will start with the control condition to minimize carry-over effects (Gondaliya &

Divecha, 2022). Randomization will be achieved using the standard Python module *random* (Python Software Foundation, 2023). Blinding refers to participants not knowing the true aim of the study; they are informed that the objective is to investigate the relationship of stress on gross motor skills and the influence of auditory stimuli on that relationship. The process for the studies is illustrated as a flowchart in Figure 1.

For each study, 40 participants who identify as female and have not participated in the other study will attend two sessions in the laboratory, each approximately 90 minutes long. Both sessions will occur within 7 days to minimize stress variations throughout the monthly cycle. Additionally, participants are required to complete an online questionnaire within 24 hours before their first session in the laboratory. This study is limited to female participants for historical accuracy. The original pellet-bell, after which the replicated pellet-bells of this study have been crafted, have been found in a burial site of women (Pomberger et al., 2021b)

After completing the study preparation phase from February to September 2023, recruitment and testing for Study 1 began in October 2023 in Vienna, Austria, at the facilities of the Department for Clinical Psychology in Adulthood at the University of Vienna. Data acquisition for Study 1 was completed between October 2023 and February 2024, and Study 2 began in April 2024 with an estimated completion date of December 2024.

2.2. Study Setting and Procedure

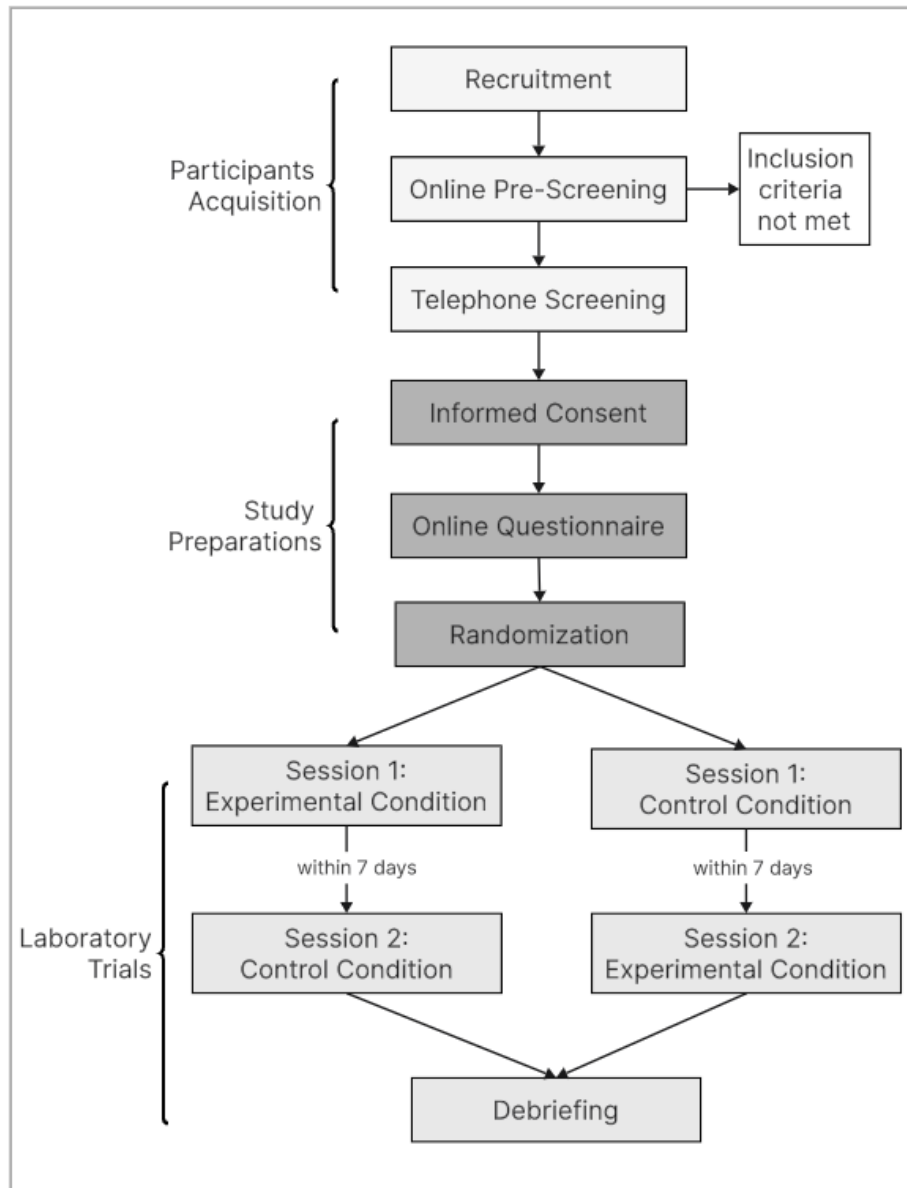


Figure 1: Flowchart of the studies process

Both appointments will be held in our laboratory. Research suggests that stress parameters are related to chronobiological rhythms (Sammito et al., 2016; Hagenauer et al., 2017). To minimize daytime-related stress variance, all appointments will be scheduled between 1 p.m. and 5 p.m. Additionally, both sessions will occur within 7 days, as stress levels can vary throughout the menstrual cycle (Jain et al., 2023). This timeframe allows for slight scheduling flexibility while maintaining consistency. Participants will also be instructed to complete the

preliminary online questionnaire within 24 hours of the first session. In the informed consent, that participants receive via email after setting the dates for their session, as well as in verbal form during a telephone call, participants will receive a list of instructions to follow in advance of their sessions. These instructions are designed to maximize stress level comparability between sessions and between participants, and to prevent artifacts in the physical measurements. Participants are asked to abstain from caffeine, alcohol, strenuous physical activities like sports, relaxation practices like yoga and from drugs on the day of their sessions, as these factors can alter stress responses and baseline stress levels (Richards & Smith, 2015; Anthenelli, 2012; Chong, 2012; Schneiderman et al., 2005; Turner et al., 2020; Schaffner et al., 2023). To avoid measurement artifacts, participants will further be asked to abstain from using skin lotion on their chest and hands, where electrodes will be attached. Additionally, they are advised not to wear brassieres with metal underwiring, which may interfere with ECG measurements. Finally, participants are asked to avoid wearing loose-fitting lower body garments to prevent silencing the pellet-bells, and to refrain from wearing noisy shoes that may mask the sound of the pellet bells. During the preparation phase of each session, participants will be asked to confirm whether they followed these instructions. Failure to adhere to the instructions will result in exclusion or rescheduling to avoid skewing the data. Sickness or the need for pain medication before the first session will also necessitate rescheduling. If these exclusion criteria arise between sessions, participants will be excluded from the study completely. By signing the informed consent, participants affirm that they have read and understood the consent form, followed the instructions, provided truthful information, and received verbal information from the scientific staff. The scientific staff member's signature confirms that they have provided comprehensive verbal information to the participant.

2.3. Study Population

To accurately investigate the research question and to ensure safety for participants of the study, narrow inclusion criteria have been defined. For historical reasons, as mentioned above, only participants identifying as female will be included in the study. Research indicates that hormonal fluctuations during puberty, perimenopause, and menopause, as well as social factors, significantly influence stress responses and overall stress levels (Tzanoulinou et al.,

2014; Papilloud, 2019; Kuck & Hogervorst, 2024). Therefore, only participants between the age 18 and 45 will be included in the study. To ensure safety during the stress-test only participants with a body mass index between 18.5 and 25 kg/m² are being included in the study, which is considered normal weight (Nuttall et al., 2015). Only participants fluent in the German language are being included, as they need to be able to follow instructions and complete questionnaires in German. Since the main stimuli of the study, the pellet-bells, are of auditory nature only participants without hearing impairments such as hearing loss or chronic and acute tinnitus are being included. An additional range of exclusion criteria that may affect stress and responses, pain perception, or inhibit participation in the study in any way were defined. If any of these holds true, the participant is not eligible for the study. The criteria are as follows:

- Chronic pain
- Visual impairment that cannot be corrected by glasses or contact lenses
- Raynaud syndrome
- Current pregnancy or breast-feeding
- Cardiovascular disease
- Hyper-/Hypotension
- Artery occlusive disease
- Alcoholism or excessive alcohol consume
- Marijuana consumption more than twice a week
- Synthetic drugs consume more than twice a month
- Current intake of pain medication
- Current intake of psychopharmaceutic
- Current mental disorders: major depression, anxiety disorder, eating disorder, substance abuse or substance addition, psychosis, schizophrenia, bipolar disorder
- Hormonal contraception

All criteria are assessed relying on self-assessment.

2.4. Recruitment, Screening, and Consent

The recruitment of participants will take place via advertisement through flyers on public notice boards, social media sites and public announcements in university classes. To maintain the study's blinding, it will be presented under the title "Step by Step. A Psychological Stress-Study", keeping in line with cover story's theme of gross-motor skills as primary field of interest. Interested individuals can scan the QR-code on the flyer or go to the link on the flyer, which leads them to a short online questionnaire hosted on Unipark (www.unipark.com) (see Appendix D). Herein all the inclusion criteria are being assessed as well as their contact information in form of email and telephone number.

If no exclusion criteria apply, participants will be contacted from a scientific staff member via phone. During the call participants will be once again asked to verify that their answers in the online questionnaire were accurate and truthful. If so, they will be informed of the gross procedure of the study as well as the necessary pre-session instructions. If they remain interested in participation, both sessions will be arranged during this call.

After the call participants receive an email with the scheduled dates, the informed consent, instructions in key-points to follow before their session and the link to the online questionnaire to be completed 24 hours before the first session. The informed consent will also be discussed verbally with a scientific staff member and signed by both parties at the start of the first session. Each participant will be compensated with 50€ at the end of the sessions. In case of premature dropout, the compensation will be proportionally.

2.5. Blinding

Participants' beliefs about a study's aim or expected outcome can alter their behaviour during the study, a phenomenon known as demand characteristics (McCambridge et al., 2012). To prevent biases resulting from demand characteristics, it is essential to blind participants to the true aims of the study. By providing a cover story, we ensure that all participants have similar beliefs and expectations about the study. Instead of indicating that the effects of historical pellet-bells are the primary interest, participants will be told that the study investigates the effects of stress on gross motor skills and the interaction of this relationship with auditory stimuli. This explanation justifies the stress test, walking paradigm, and pellet bells without

focusing participants' expectations on the study's true aims. To enhance credibility of the fake story, a camera will be set up. Contrary to the participants knowledge the camera will at no time be recording. The true aims of the study and the necessity for blinding will be explained during the debriefing at the end of the second session. Participants will also be asked to keep this information confidential to avoid informing potential future participants.

2.6. Materials and Equipment

2.6.1. Stress Induction and Relaxation

In Study 1, the cold pressor test (CPT) will be used for stress and pain induction (Lovallo, 1975). This safe method of stress induction is frequently employed in psychological and medical research (Ruscheweyh, 2010). This method has originally been developed for pain induction but has recently seen growing use as a measure of stress induction for its consistent results (Drosta et al., 2024). The CPT was chosen over other stress induction methods due to its ability to be used repeatedly with relatively little habituation (Bullock et al., 2023), which is essential as it will be used in both the experimental and control conditions.

The CPT involves subjects immersing one or multiple extremities in ice-cold water, typically between 1°C and 4°C. In this study, participants will place their dominant hand in the water. A bucket filled with water will be used, with ice at the bottom to cool the water and maintain the target temperature. The ice is separated from the area where participants place their hands to prevent direct contact, which could damage tissue. An electric pump will circulate the water to ensure a constant temperature throughout the bucket. Before the test starts, the water temperature is measured to ensure it is in the desired range.

Participants will be instructed to immerse their dominant hand up to the wrist in the water bucket and to keep it there as long as possible, removing it only when they can no longer tolerate to keep the hand in, which they will indicate verbally to the examiner. During this procedure, the examiner will face away from the participant to reduce social pressure. The duration of the hand's immersion will be timed without the participants knowing. After a maximum of 3 minutes, the examiner will instruct the participant to remove their hand to avoid potential tissue damage.

In Study 2, participants will be exposed to nature sounds to facilitate relaxation. Specifically, a 10-minute recording of water rippling will be utilized. This auditory stimulus will be delivered through Audio-Technica ATH-M50 over-ear headphones.

2.6.2. Pellet-Bells

The idiophones used in these studies were selected based on a preliminary study by Pomberger et al. (in press). The selection criteria included high- and low-arousal evaluations, comparability, and historical accuracy. For Study 1, a replica of a copper pellet-bell and for Study 2, a replica of an iron pellet-bell were chosen as the copper pellet-bell was rated particularly low in arousal and the iron pellet-bell was rated particularly high in arousal (Foramitti, 2024). Their original counterparts were excavated from a woman's burial site in Komárno (Lodenica), Slovakia, dating back to the 8th century AD during the Avar period. The replicas have a frequency range from 2 kHz to 4.5 kHz. Both pellet-bells are similar in weight, with the copper pellet-bell weighing 14.27 g and the iron pellet-bell 15.13 g (Mühlhans et al., 2022).

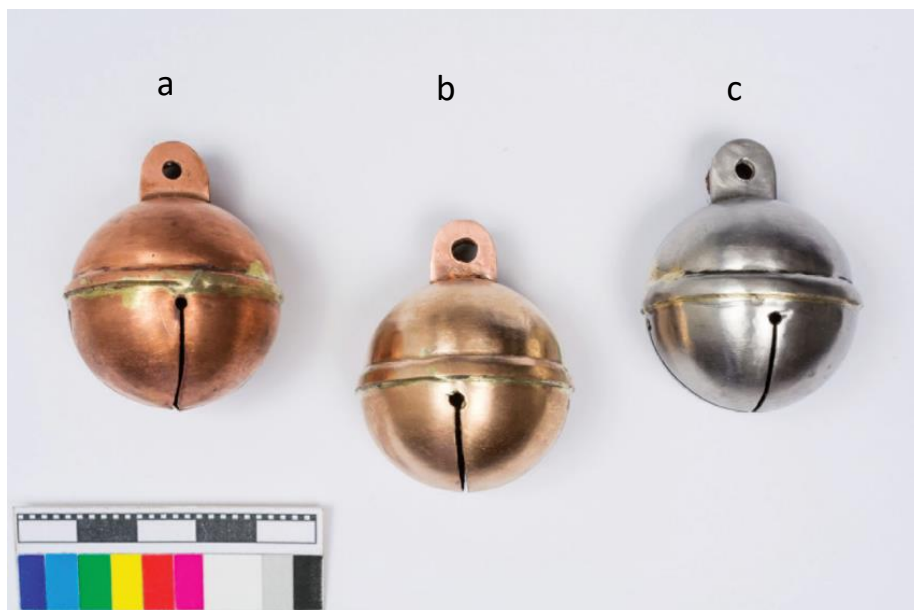


Figure 2: Replicates of a pellet-bell found in Komárno (Photo by L. Kerbler; Mühlhans et al., 2022) low-arousal copper pellet-bell (a); bronze pellet-bell (b, not used in the current studies); high-arousal iron pellet-bell (c)

In Pomberger et al.'s study (in press), the sound of the iron pellet-bell was rated significantly higher in brightness, sharpness, and arousal compared to the sound of the copper pellet-bell. These subjective evaluations of psychoacoustic parameters were also supported by audio

spectrum analysis using Fast Fourier Transformation (Mühlhans et al., 2022). As part of the project "Metallic Idiophones between 800 BC and 800 AD in Central Europe" at the Natural History Museum Vienna (Pomberger et al., 2021a), material analyses of the originals were conducted and exact replicas were produced, ensuring historical accuracy of the idiophones. However, it should be noted that the sounds of the originals and replicas cannot be directly compared due to changes in the sound of the originals over time due to corrosion (Pomberger et al., 2021a). Further detailed information on the pellet-bells can be found in Mühlhans et al. (2022), Pomberger et al. (2023), Pomberger et al. (2021b) and Mühlhans and Pomberger (2023). The silent control pellet-bell was created by removing the pebble from within a pellet-bell of similar size and weight as the replicated pellet-bells, rendering it unable to produce sound.

In these studies, the pellet-bells will be worn by participants as they were presumed to be historically used, based on analyses of excavations and historic artifacts such as paintings. Historically, these pellet-bells were commonly worn attached to belts, in belt pouches, or on the sleeve, positioned at the right or left thigh between the knee and pelvis (Pomberger et al., 2021b). Accordingly, in the present studies, the pellet-bells will also be attached to a belt with a string, positioned between the pelvic and knee. Since historical evidence does not specify a preference for left or right sides, the pellet-bells will consistently be attached to the non-dominant side of participants in these studies for consistency and comparability.

2.6.3. Stress Measurements

Stress is recognized as a multidimensional construct that manifests itself in various ways (Nater, 2018). The current studies aim to assess stress comprehensively through both biological and subjective measurements. The biological aspect of stress can be subdivided into autonomic pathways, assessed via HRV, EDA and sAA levels; and endocrine pathways, measured through salivary cortisol levels (Nater et al., 2013). Given that these measurements reflect distinct physiological pathways, they require separate interpretation (Nater, 2018).

In each session of the current studies stress will be assessed five times as baseline, post-stress-test for Study 1 or post-relaxation for Study 2, post-intervention 1, post-intervention 2 and post-intervention 3. Stress will each time be assessed via HRV, EDA, sAA, salivary cortisol and

self-assessment. All five measurements will be taken simultaneously within a 2-minute window.

2.6.3.1. Heart Rate Variability

HRV is regarded as a valuable marker for stress due to its reflection of ANS activity, which regulates the heart's rhythm in response to stressors. High HRV typically indicates a well-functioning autonomic nervous system and a relaxed state, while low HRV is associated with increased stress and reduced adaptability to stressors. This variability is influenced by various factors including emotional stress, physical activity, and overall cardiovascular health. As a non-invasive measure, HRV provides valuable insights into an individual's stress response and overall autonomic balance (Peabody et al., 2023; Shaffer et al., 2017).

HRV is a measure of the variation in time intervals between consecutive heartbeats. These interbeat intervals (RR) are commonly assessed by measuring the time intervals between consecutive R-waves in the ECG cycle. The R-waves are the peaks in the QRS complex, representing ventricular depolarization in the heart (Shaffer et al., 2017).

For the current studies, the Movisens EcgMove 4 mobile monitor (www.movisens.com) will be used, which records a single-channel ECG with a sampling frequency of 1024 Hz using the Movisens chest-belt equipped with two built-in dry electrodes. Each measurement will last two minutes, during which the root mean square of successive RR interval differences (RMSSD) will be calculated as a measurement of HRV. RMSSD is a suggested metric for ultra-short-term HRV assessment (Shaffer et al., 2016).

The analysis of the HRV will be conducted using a custom Python script (see Appendix A). The BiospPy package (Carvalho et al., 2019), NumPy package (Harris et al., 2020), Matplotlib package (Hunter, 2007), and Pandas (pandas-dev/pandas, 2020) are utilized to segment the ECG data around each marker and detect R peaks within these segments. The RR intervals, representing the time differences between consecutive R peaks, are then computed. For HRV analysis, the hrvanalysis package (Kubios Oy, 2020) is employed. Outliers are removed from the RR intervals, and time-domain HRV metrics, including the root mean square of successive differences (RMSSD), are calculated. RMSSD is calculated as:

$$RMSSD = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N-1} (RR_{i+1} - RR_i)^2}$$

where RR_i and RR_{i+1} are successive RR intervals, and N is the total number of RR intervals.

2.6.3.2. Electrodermal Activity

EDA, or galvanic skin response, serves as stress marker by reflecting sympathetic nervous system activity, which governs the sweat gland response to stressors. Increased EDA indicates heightened sympathetic arousal and stress reactivity, while decreased EDA suggests lower physiological arousal and relaxation (Boucsein, 2012; Benedek & Kaernbach, 2010). This physiological response is influenced predominantly by emotional and cognitive stressors, providing a non-invasive means to assess stress levels and autonomic nervous system regulation.

In the current studies EDA will be measured with the Movisens EDA Move 4 mobile monitor (www.movisens.com). This monitor measures single channel EDA with a sampling frequency of 32 Hz by applying a DC voltage of 0.5V through two pre-gelled Ag/AgCl adhesive electrodes (www.movisens.com). The electrodes will be fixed to the participants non-dominant hand, one at the height of the *Os Metacarpale V* and one at the height of the *Os Triquetrum*. For each measurement the mean microsiemens (μS) will be calculated as the value for EDA with a custom Python script (see Appendix B).

2.6.3.3. Salivary Alpha Amylase

sAA serves as an additional biomarker of stress, reflecting sympathetic nervous system activation, which stimulates its release into saliva in response to acute stressors. Increased sAA indicates heightened sympathetic arousal and physiological stress response, whereas decreased activity may signify lower stress levels and relaxation (Ali & Pruessner, 2012; Nater & Rohleder, 2009; Nater et al., 2015). This enzymatic response is primarily influenced by psychological stressors, providing a non-invasive method to assess stress levels and sympathetic nervous system modulation (Ali & Nater, 2020).

In the current studies, salivary samples will be collected to analyze sAA levels (measured in U/ml). The analysis will employ the enzyme kinetic method (Engert et al., 2011), which allows for precise quantification of sAA activity in saliva. This methodological approach ensures accurate assessment of SNS activity and stress response in participants.

2.6.3.4. Salivary Cortisol

Salivary cortisol serves as a biomarker of stress, reflecting HPA axis activation, which triggers cortisol release into saliva and blood in response to stress. Increased cortisol levels indicate heightened HPA axis activity and physiological stress response, whereas decreased levels may signify lower stress levels and relaxation (Hellhammer et al., 2009). The hormonal response provides a non-invasive method to assess stress levels and neuroendocrine modulation (Stalder et al., 2016).

From the collected salivary samples, cortisol levels (expressed in nmol/l) will be analyzed using a time-resolved fluorescence immunoassay (Dressendörfer et al., 1992). This method is well-established for measuring cortisol concentrations in saliva, providing a sensitive and reliable means to assess the hormonal response to stress.

2.6.3.5. Psychological assessment

Additionally, to the above-mentioned biomarkers, psychological self-assessment of stress provides valuable insights into individuals' subjective experience of stress. We will assess momentary subjective stress and momentary subjective pain with two paper-pencil Visual Analog Scales (VAS) at each measurement. Participants will rate their current level of stress and their current level of pain by marking a point on a scale ranging from 0 (not at all) to 100 (very much) in response to the questions "How much does the following statement fit to your current state: I feel stressed" and "How much does the following statement fit to your current state: I am in pain".

Also, for each measurement they will complete the German version of the Multidimensional Mood Questionnaire (MDBF; Wilhelm & Schoebi, 2007). On this 6-item inventory they must rate their current mood by means of six bipolar items: relaxed-tense [entspannt-angespannt],

unwell-well [unwohl-wohl], full of energy-without energy [energiegeladen-energielos], agitated-calm [unruhig-ruhig], tired-awake [müde-wach], content-discontent [zufrieden-unzufrieden].

2.6.4. Preliminary Questionnaires

As multiple factors may affect the stress response to an auditory stimulus, a range of tertiary variables will be assessed for exploratory control, moderator, and/or mediator analysis. To that end, participants must fill out an online questionnaire hosted on Unipark (www.unipark.com) in advance of their first session. The questionnaire includes German versions of the following inventories:

- Patient Health Questionnaire (PHQ; Löwe et al., 2002): A self-administered tool for assessing mental and physical health conditions.
- Music Preference Questionnaire (MPQ-R; Nater et al., 2005): Evaluates individual differences in music preferences.
- Perceived Stress Reactivity Scale (PSRS; Scholtz et al., 2011): Measures how individuals perceive their reactivity to stress.
- Screening Scale for Chronic Stress from the Trier Inventory for Chronic Stress (TICS; Schulz et al., 2004): Assesses chronic stress levels over the past three months.
- Premenstrual Syndrome Questionnaire (PMS; Ditzen et al., 2011): Assesses the severity of premenstrual symptoms, which could influence stress responses.
- Standard socioeconomic questions: Collect demographic information such as age, education and employment status.

2.6.5. Microphone and Audio Recording

The Zoom H2 Handy Recorder microphone will be used to record audio during the walking paradigm (Zoom Corporation, 2023). This microphone allows for relative loudness comparison but not for absolute loudness measurement. Audio recordings will utilize the microphone's 4-channel recording capabilities, enabling a 360° surround sound representation. The microphone will be positioned at the centre of the walking paradigm setup.

After recording, the audio files will be edited using Audacity software (Audacity Team, 2023). In Audacity, the multiple channels will be merged, and the audio will be edited according to the study's requirements, specifically removing verbal instructions given to participants. Loudness will be calculated using root mean square (RMS) values to compare relative loudness levels (Sharma et al., 2020). These calculations will be conducted using a Python script (see Appendix C) with the LibROSA package (McFee et al., 2015). RMS is calculated as:

$$RMS = \sqrt{\frac{1}{N} \sum_{n=1}^N y[n]^2}$$

where $y[n]$ represents the amplitude of the audio signal at time n , and N is the total number of samples.

2.7. Procedure

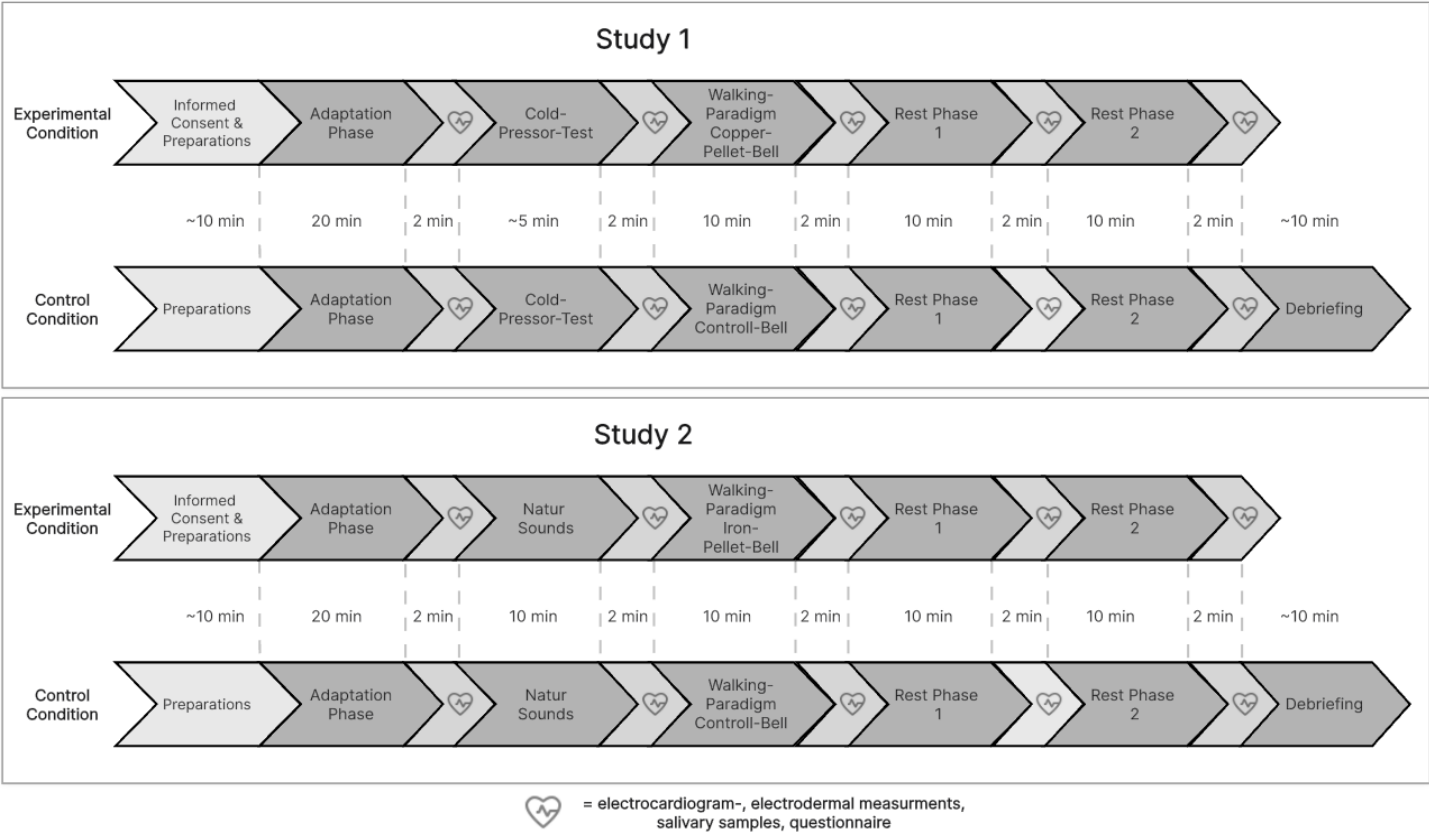


Figure 3: Procedure of Study 1 and Study 2

Both Study 1 and Study 2 have similar procedures with the only difference being the stimulus and the stress induction. Study 1 will use a low-arousal copper pellet-bell and a stress-test, while Study 2 will use a high-arousal iron-bell and relaxing audio presentation. The studies procedures can be seen in Figure 3.

2.7.1. Procedure Study 1

At the start of their first session, after discussing informed consent, participants will be informed about the general procedure of the sessions. Subsequently, they will be equipped with both ECG and EDA measurement systems. To ensure participants start the session with a relatively normal baseline stress state, a 20-minute adaptation phase will follow, during which participants will be left alone to read magazines.

After the adaptation phase, participants will be equipped with either the low-arousal copper pellet-bell for the experimental condition or the silent pellet-bell for the control condition. Baseline measurements will be taken. Afterwards, subjects will undergo the CPT with subsequent post-stress-test measurements. Following this is the 10-minute walking paradigm.

During the walking paradigm, participants will walk along a 250 cm x 250 cm square with 5 equidistant floor markings on each side. They will perform four different walking patterns, each lasting 2 minutes and 15 seconds, with 15 seconds of instruction between each pattern. They will be instructed to perform the walking pattern at their normal walking tempo until they receive new instructions. For the first session, participants will:

1. Walk along the lines of the square from corner to corner.
2. Walk slalom around the individual markings of the square.
3. Walk sideways along the square facing the centre.
4. Walk sideways along the square facing away from the centre.

For the second session, participants will perform the walking patterns in reverse order to avoid practice effects.

After the walking paradigm, the post-intervention 1 measurements will be assessed. Following this are two 10-minute rest periods, with post-intervention 2 and post-intervention 3 measurements taken after each rest period. These rest periods are necessary due to the delayed secretion and breakdown of cortisol (McEwan, 2007). For the second session, an extensive debriefing will follow the final measurements.

2.7.2. Procedure Study 2

The procedure of Study 2 follows that of Study 1, with two key differences. Instead of the CPT, participants will be presented with a 10-minute audio file of nature sounds. Additionally, in the experimental condition, participants will be equipped with a high-arousal iron pellet-bell. For the control condition, the same silent pellet-bell used in Study 1 will be utilized.

2.8. Sample Size Determination

There has not been a study with comparable design and research interest giving indications of an expectable effect size. Yet, in the study of Pomberger et al. (in press), the sounds of the pellet bells were being evaluated significantly differently in their sound's arousal. This was taken into consideration for a sample size calculation of the present studies by assuming a medium effect size. For these within-subject design studies with repeated measurements, a power analysis using G*Power 3 (Faul et al., 2007) yielded a sample size of 32 participants per study ($f=.25$; $p=.05$; $k=5$; $1-\beta=.95$). To account for dropouts the target sample size was set at 40. This is in line with suggestions for pilot laboratory-based pilot studies (Moore et al., 2011; Bell et al., 2018; Lancaster et al., 2004)

2.9. Statistical Analysis

We will conduct within-subject repeated-measures analyses of variance for hypotheses 1 and 2 in both studies while controlling for the baseline measurements. Individual stress parameters for hypothesis 1 will be analysed separately from each other as they reflect distinct physiological pathways. For all calculations a P-value of ≤ 0.05 will be considered statistically significant. Any further exploratory analyses that arise will be explicitly outlined in future publications. In the event of missing data, we will implement imputation methods as specified by Molenberghs and Kenward (2007). Data analysis will be conducted using Python (Python Software Foundation, 2023). The following packages will be utilized: NumPy (Harris et al., 2020); Pandas (pandas-dev/pandas, 2020); SciPy (Virtanen et al., 2020); Statsmodels (Seabold & Perktold, 2010); Scikit-learn (Pedregosa et al., 2011).

2.10. Ethical Considerations

The study has been approved by the Local Ethics Committee of the University Vienna with no ethical objections found. Before participating in the study, potential participant will receive comprehensive information outlining the study's procedure. To effectively test our research question, blinding participants regarding the study's true objective is necessary. Yet, the blinding is limited to a cover story regarding the outcome and participants will be extensively debriefed after their second session on the true aims of the study and necessity for blinding.

To induce stress in Study 1, participants will undergo the CPT. While this test may induce discomfort, participants will have the option to remove their hand from the water at any point. For safety reasons, the maximum immersion duration will be limited to 3 minutes. To further ensure participants safety, individuals with pre-existing conditions such as cardiovascular or other chronic diseases will be excluded from participating.

2.11. Confidentiality and Data Management

To ensure confidentiality, each participant will be randomly assigned a study code in the form of a sequential number. All data, including information from the online questionnaire and laboratory sessions, will be stored using these codes. Only scientific staff members actively working for the study will have access to a list linking these codes to participants. This allows participants to withdraw their data from the studies within 6 weeks following their participation. After this period, the list will be destroyed, preventing any connection between individuals and collected data. Physical data will be stored securely in a locked cabinet, while digital data will be saved on a secure internal password-protected server.

3. Discussion

Auditory stimuli have been suggested to have positive effects on health, particularly stress, by a range of studies (Chafin et al., 2004; Gan et al., 2016; Koelsch et al., 2016), while other studies did not find similar effects (Fallon et al., 2020; Labbé et al., 2007; Raadstaak et al., 2004;

Sokhadze, 2007). Most previous research has focused on music or nature sounds as primary auditory stimuli and their health benefits, such as stress reduction. The current studies aim to address this gap by investigating two distinct auditory stimuli: the sounds of two pellet-bells made from different materials, selected based on their previously assessed arousal levels by Pomberger et al. (in press). Additionally, these studies will contrast the stress-reducing effects of a low-arousal auditory stimulus with the stress-inducing effects of a high-arousal auditory stimulus, while maintaining a comparable study design for further exploratory research. The interest of these studies is novel, as it combines previous psychological stress research with archaeological research. While the main objective of this study remains with investigating whether metallic idiophones may have been worn by past civilisations due to their effects on humans themselves, as first proposed by Pomberger et al. (2021b), it is designed to enable inferences about auditory-based stress interventions more generally.

Certain limitations of these studies must be considered. Since the pellet-bells used in these studies were excavated from a woman's burial site, only participants who identify as female are included to enhance historical accuracy. However, this limits the generalizability of the stress-altering effects of the stimuli to a broader population. Additionally, it should be noted that metallic idiophones have been found in the burial sites of not only women but also men and children (Pomberger et al., 2021b). Therefore, any historical inferences must be limited to the pellet bells used in the current studies.

Furthermore, as suggested by Pomberger et al. (in press), the perceived arousal levels of metallic idiophones vary along a scale. To streamline the current studies, we have chosen to focus on two extremes: a high-arousal idiophone and a low-arousal idiophone. However, for future research, expanding to include a broader range of stimuli would be beneficial. This approach would allow for more nuanced interpretations and a deeper understanding of how different levels of arousal in idiophones impact stress responses and other psychological outcomes. Expanding the range of stimuli could provide insights into the dose-response relationship between idiophone arousal and stress modulation, helping to refine intervention strategies aimed at utilizing auditory stimuli for therapeutic purposes. Additionally, it would facilitate comparisons across different types of idiophones and enhance the generalizability of findings to diverse populations and settings. Incorporating a wider spectrum of idiophones in future studies would also align with evolving research methodologies that seek to

comprehensively explore the therapeutic potential of auditory stimuli in stress management and psychological well-being.

Another limiting factor of the current studies is the assessment of the menstrual phase via the self-assessment inventory PMS. The menstrual cycle affects stress response (Jain et al., 2023), and inaccuracies in self-assessment could influence the interpretation of stress biomarkers. Although self-assessment is a convenient and non-invasive method, it is subject to individual variability and recall bias, which may lead to misclassification of menstrual phases. This, in turn, could affect the reliability of the stress measurements and potentially confound the results. Future studies might benefit from more objective methods of assessing menstrual phase, such as hormonal assays, to enhance accuracy and reliability in interpreting the impact of menstrual cycle variations on stress responses.

Finally, the CPT, a commonly used method for stress and pain induction in psychological and medical research, is frequently debated for its reliability. Some studies suggest desensitization effects due to repeated exposure to the CPT (Lamotte et al., 2021). However, a growing body of research suggests non-desensitization and consistent ANS activity upon repeated exposure to the CPT, provided there is sufficient recovery time between exposures (Blacker et al., 2012; Minkley et al., 2014; Windesheim et al., 1955). According to the study's design, sufficient recovery time is ensured. Moreover, if any desensitization occurs, it would likely affect all participants equally, thereby minimizing its impact due to randomization. For exploratory analysis, comparing baseline and post-stress-test measurements can confirm the CPT's consistent stress-inducing effects.

The current studies represent a significant advancement in understanding the stress-reducing and inducing potential of auditory stimuli, specifically metallic idiophones, in stress management. By systematically investigating the effects of high- and low-arousal auditory stimuli on stress responses, these studies bridge gaps in both psychological stress research and archaeological inquiry. Previous research has predominantly focused on well-established auditory stimuli like music and nature sounds, primarily examining their stress-reducing effects. In contrast, the current studies explore how metallic idiophones, artifacts with historical significance, may have influenced stress levels in past civilizations.

What distinguishes this study is its methodological rigor in measuring stress through both biological markers and subjective assessments. By employing physiological measures

alongside self-reported stress indicators, the study offers a comprehensive evaluation of stress responses. This dual approach not only enhances the reliability and validity of the findings but also provides a nuanced understanding of how auditory stimuli impact stress at multiple levels of analysis.

Moreover, the inclusion of historical artifacts like metallic idiophones adds a novel dimension to stress intervention research. By examining these artifacts within a controlled experimental setting, the study enables insights into their potential therapeutic applications across different contexts and populations. This interdisciplinary approach not only advances our scientific understanding of stress modulation but also enriches our appreciation of cultural artifacts and their potential contributions to human well-being.

In conclusion, this study is pivotal in advancing our knowledge of auditory-based stress interventions, leveraging historical insights to inform contemporary practices. By integrating diverse disciplines and methodologies, the study sets a benchmark for future research aimed at harnessing auditory stimuli for stress management and psychological well-being.

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List of Abbreviations

ANS	autonomic nervous system
CPT	cold pressor test
ECG	electrocardiogram
EDA	electrodermal activity
HPA	hypothalamic-pituitary-adrenal axis
HRV	heart rate variability
MDBF	Multidimensional Mood Questionnaire
MPQ	Music Preference Questionnaire revised
PHQ	Patient Health Questionnaire
PMS	Premenstrual Syndrome Questionnaire
PNS	parasympathetic nervous system
PSRS	Perceived Stress Reactivity Scale
RMS	root mean square
RMSSD	root mean square of successive interbeat interval differences
RR	interbeat interval
sAA	salivary alpha amylase
SNS	sympathetic nervous system
TICS	Trier Inventory for Chronic Stress
VAS	visual analog scale

Appendix A

Appendix A contains the Python code for HRV-analysis, setup for Jupyter-Notebook and Python 3.9

```
# This first part is for verifying the data is useable for analysis
# Here we check if the marker for measurements have been set correctly
import pandas as pd
import matplotlib.pyplot as plt

# Set the paths to the ECG and Marker file for analysis
ecg_file_path = r"\ecg.csv"
marker_file_path = r"\marker.csv"

df_ecg = pd.read_csv(ecg_file_path, header=None, names=['Ecg Data'])

ecg_marker = pd.read_csv(marker_file_path, header=None, names=['Marker'])

ecg_marker1 = int(ecg_marker['Marker'].str.split(';').str.get(0).iloc[0])
ecg_marker2 = int(ecg_marker['Marker'].str.split(';').str.get(0).iloc[1])
ecg_marker3 = int(ecg_marker['Marker'].str.split(';').str.get(0).iloc[2])
ecg_marker4 = int(ecg_marker['Marker'].str.split(';').str.get(0).iloc[3])
ecg_marker5 = int(ecg_marker['Marker'].str.split(';').str.get(0).iloc[4])

list_of_ecg_marker = (ecg_marker1, ecg_marker2, ecg_marker3, ecg_marker4, ecg_marker5)
print(list_of_ecg_marker)

plt.figure(figsize=(30, 12))
plt.plot(df_ecg['Ecg Data'])
plt.title('Ecg Data', fontsize=40)
plt.xlabel('Sample', fontsize=20)
plt.ylabel('Ecg Value', fontsize=20)

for marker in list_of_ecg_marker:
    plt.axvline(x=(marker), color='red', linestyle='--')

plt.savefig('ecg_plot.png')

plt.show()

# This part is for HRV-analysis. Only run if data was checked first
```

```

import pandas as pd
import numpy as np
import biosppy.signals.ecg as ecg
import matplotlib.pyplot as plt
from hrvanalysis import remove_outliers, get_time_domain_features

# Set the paths to the ECG and Marker file for analysis
ecg_file_path = r"\ecg.csv"
marker_file_path = r"\marker.csv"

sample_frequency = 1024
time_int_min = 2
# Marker correction for when marker have a different sample frequency then ecg.
marker_correction = False

# Step 1: Read ECG Data from CSV File
ecg_data = pd.read_csv(ecg_file_path, header=None, names=['ECG Data'])
ecg_marker = pd.read_csv(marker_file_path, header=None, names=['Ecg Marker'])

# Extract markers
if marker_correction:
    markers = ecg_marker['Ecg Marker'].str.split(';').str.get(0).astype(int) * 16
    print("*****\n"
          "WARNING: Marker Correction\n"
          "*****")
else:
    markers = ecg_marker['Ecg Marker'].str.split(';').str.get(0).astype(int)

# List to store HRV features
hrv_data = []

i = 0

# Iterate through each marker
for ecg_marker_value in markers:

    ecg_start_row = ecg_marker_value - (sample_frequency * (60 * time_int_min))
    ecg_end_row = ecg_marker_value
    ecg_segment = ecg_data['ECG Data'].iloc[ecg_start_row:ecg_end_row].values

    # Step 3: Detect R Peaks
    rpeaks = ecg.ecg(signal=ecg_segment, sampling_rate=1024)['rpeaks']

```

```

plt.figure(figsize=(20, 10))
plt.plot(ecg_segment, color='black', label='ECG')
plt.plot(rpeaks, ecg_segment[rpeaks], 'ro', label='R peaks')
plt.title(f"R Peak Detection (Marker {i+1})")
plt.xlabel('Sample')
plt.ylabel('ECG Amplitude')
plt.legend()
plt.grid(True)
plt.show()

# Step 4: Calculate RR Intervals
rr_intervals = np.diff(rpeaks)

# Step 5: Calculate HRV Metrics
hrv_features = get_time_domain_features(rr_intervals)

# Append HRV metrics to list
hrv_data.append({'Marker': ecg_marker_value,
                'SDNN': hrv_features['sdnn'],
                'RMSSD': hrv_features['rmssd'],
                'Mean HR': hrv_features['mean_hr']})

i += 1

# Create DataFrame from the list
hrv_df = pd.DataFrame(hrv_data)

print(hrv_df)

# Save DataFrame to Excel file
hrv_df.to_excel(r'hrv_metrics.xlsx', index=False)

```

Appendix B

Appendix B contains the Python code for EDA-analysis, setup for Jupyter-Notebook and Python 3.9

```

import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import os

```

```

# Initialize an empty list to store all results
all_eda_results = []

# Loop through VPN numbers
for vpn_number in range(1, 41):
    for bed_number in range(1, 3): # Bed1 and Bed2
        vpn = f"VPN{vpn_number:02}_Bed{bed_number}"
        eda_file_path = r"{}_Eda\eda.csv".format(vpn)
        eda_marker_file_path = r"{}_Eda\marker.csv".format(vpn)

        try:
            if not os.path.exists(eda_file_path) or not os.path.exists(eda_marker_file_path):
                raise FileNotFoundError("File not found.")

            eda_data = pd.read_csv(eda_file_path, header=None, names=['Eda Data'])
            eda_marker = pd.read_csv(eda_marker_file_path, header=None, names=['Eda Marker'])

            markers = eda_marker['Eda Marker'].str.split(';').str.get(0).astype(int) // 2
            eda_results = []

            for i, eda_marker_value in enumerate(markers):
                eda_start_row = eda_marker_value - (32 * 60 * 2)
                eda_end_row = eda_marker_value
                eda_segment = eda_data['Eda Data'].iloc[eda_start_row:eda_end_row].values
                mean_eda = np.mean(eda_segment) / 100
                eda_results.append({'VPN': vpn, 'Bed': bed_number, 'Marker': eda_marker_value,
'Eda': mean_eda})

                plt.figure(figsize=(30, 12))
                plt.plot(eda_segment)
                plt.title(f'EDA Data Measurement {i+1} - {vpn} - Bed{bed_number}',
fontsize=30)
                plt.xlabel('Sample', fontsize=20)
                plt.ylabel('EDA Value', fontsize=20)
                plt.ylim(0, 25000)
                plt.text(0.5, 0.95, f'Mean EDA: {mean_eda:.2f}',
transform=plt.gca().transAxes,
                fontsize=30, verticalalignment='top', bbox=dict(boxstyle='round',
alpha=1))

                plt.show()

            # Extend the list of all results with the current results

```

```

        all_eda_results.extend(eda_results)

    except FileNotFoundError as e:
        print(f"Warning: {e}")

# Create a DataFrame from the list of all results
all_eda_df = pd.DataFrame(all_eda_results)

# Save DataFrame to Excel file
all_eda_df.to_excel(r'all_eda_values.xlsx', index=False)

print(all_eda_df)

```

Appendix C

Appendix C contains the Python code for RMS-analysis, setup for Jupyter-Notebook and Python 3.9

```

import librosa
import numpy as np

audio_file = "audio_recording.wav"

y1, sr1 = librosa.load(audio_file1)
rms1 = np.mean(librosa.feature.rms(y=y1))

print("Mean RMS for {}: {}".format(audio_file1, rms1))

```

Appendix D

Online-Prescreening

Vielen Dank für Ihr Interesse an unsere Studie teilzunehmen!

Im Folgenden finden Sie einige Fragen, die wir Sie bitten auszufüllen. Bitte beantworten Sie alle Fragen gewissenhaft.

Alle Angaben werden von uns diskret behandelt und dienen ausschließlich dazu festzustellen, ob Sie für unsere Studie geeignet sind.

Das Ausfüllen wird ca. 5 min dauern.

Geben Sie bitte hier Ihren vollständigen Namen an.

Telefonnummer für Kontaktaufnahme:

Email-Adresse für Kontaktaufnahme:

Mit welchem Geschlecht identifizieren Sie sich?

- weiblich
- männlich
- divers
- andere:

Ist Deutsch Ihre Muttersprache?

- Ja
- Nein

Sprechen Sie fließend Deutsch?

- Ja
- Nein

Wie alt sind Sie?

Wie viel wiegen Sie? (in kg)

Wie groß sind Sie? (in cm)

Sind Sie aktuell schwanger oder stillen Sie derzeit?

- Nein
- Ja

Leiden Sie an einer der folgenden Krankheiten oder wurde eine der folgenden Krankheiten bei Ihnen diagnostiziert?

- Herz-Kreislauf-Erkrankung
- arterielle Verschlusskrankheit
- Bluthochdruck oder niedriger Blutdruck
- chronische Schmerzen
- Diabetes

- Raynaud-Syndrom
- Schädigung des Gehörs, z.B. chronischer Tinnitus, Hörbeeinträchtigungen
- keine

- Andere:

Sind Sie in Ihrer Sehfähigkeit stark eingeschränkt?

(starke Einschränkung, die nicht durch eine Brille/Kontaktlinse behebbar ist)

- Nein
- Ja

Konsumieren Sie regelmäßig harte Drogen?

- Synthetische Drogen mehr als 2x im Monat (Bsp. MDMA/Ecstasy)
- Cannabis mehr als 2x pro Woche
- Nein
- Andere:

Nehmen Sie regelmäÙig folgende Medikamente ein?

- Hormonelle Kontrazeptiva (z.B. "Pille")
- Schmerzmedikamente
- Psychopharmaka
- Nein
- Andere Medikamente:

Verwenden Sie momentan hormonelle Verhütungsmittel?

- Nein
- Ja

Leiden Sie aktuell unter einer diagnostizierten psychischen Störung?

- Nein
- Ja, aktuelle Major Depression oder Angststörung
- Ja, aktuelle Essstörung
- Ja, aktuelle Substanzabhängigkeit (Alkohol, Drogen, Medikamente, Nasenspray,...)
- Ja, Psychose/Schizophrenie
- Ja, andere

Danke für Ihre Teilnahme!

Wir werden uns in Kürze bei Ihnen melden, falls Sie für unsere Studie geeignet sind.

Bei weiteren Fragen wenden Sie sich bitte an psychomotorik.studie@gmail.at

Verantwortlich für diese Studie ist Markus Foramitti

Appendix E: German Abstract

Abstract

Angesichts der schweren Auswirkungen von Stress auf sowohl langfristige als auch kurzfristige physische und psychische Gesundheit hat die Erforschung von Stimuli, die Stress auslösen oder lindern, erheblich an Bedeutung gewonnen. Historische Quellen deuten darauf hin, dass Stress und dessen Reduktion bereits in vergangenen Kulturen ein wichtiges Anliegen waren. Diese Studie, die Teil des Projekts „Metallic Idiophones in Central Europe between 800 AD and 800 BC“ (Pomberger et al., 2021a) ist, untersucht die historische Bedeutung metallischer Idiophone und stellt die Theorie auf, dass diese Instrumente möglicherweise aufgrund ihrer Auswirkungen auf Menschen, spezifisch auf Stress, getragen wurden. Das Projekt untersucht ausgegrabene Idiophone durch interdisziplinäre Ansätze, die Archäologie, Akustik und Psychologie umfassen, um deren kulturelle Motivationen und Effekte zu verstehen. Die vorliegende empirische Forschung umfasst zwei Studien, die die stressverändernde Wirkung historischer Idiophone anhand eines randomisierten Kontrollstudiendesigns untersuchen. Die erste Studie untersucht mögliche stressreduzierende Wirkungen einer Schelle mit wenig aktivierendem Klang nach einem Stressor (Cold Pressor Test). In der zweiten Studie wird die stressauslösende Wirkung einer Schelle mit stark aktivierendem Klang nach Entspannung (durch Naturklänge) untersucht. Stress wird hormonell, kardiovaskulär und subjektiv erfasst. Ziel dieser Studien ist es weitere Erkenntnisse über Stress modulierende Wirkungen von auditiven Stimuli zu generieren und gleichzeitig die kulturellen Beweggründe für den Einsatz metallischer Idiophone in vergangenen Gesellschaften zu beleuchten.

Schlüsselwörter: Stress, Musikwissenschaft, Archäologie, Psychologie, Psychoakustik, Cold Pressor Test