Pain Creature: interdisciplinary collaboration in the design of an embodied textile instrument for interactive dance

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ABSTRACT

This paper describes the development of an interactive textile instrument called Pain Creature. The instrument is the result of a collaboration between a sonic interaction designer and a textile designer. Through textile and auditory qualities, Pain Creature explicates different aspects of the second author's experience of chronic pain. The instrument can be used as a tool to reflectively engage with the user's pain experiences and as a performance instrument. This paper introduces the collaborative design process employed to develop the artifact, focusing on how contributions from sound design, textile design and movement practice were combined in the design phase. The paper describes the technical design of the artifact and discusses how knowledge from different disciplines affected the development of the instrument and its use in performance.

Author Keywords

Embodied interface, Design process, Interactive dance, Interdisciplinary collaboration

CCS Concepts

•**Applied computing** → **Sound and music computing;** Performing arts;

1. INTRODUCTION

Embodied musical interfaces have been a popular research topic in recent years, due to advancements in sensors, e-textiles and microcontrollers. Embodied instruments have been employed in new music research to investigate the connection of gesture and sound in the context of dance and instrumental practice [5, 56]. Novel fabrics and e-textiles have been extensively used for embodied digital interfaces in Human-Computer Interaction [46], and they have been employed in the musical domain to develop interactive costumes for dance [36, 3, 18] and tactile instrument controllers [57, 28, 49]. Designing such interfaces often requires collaborating with practitioners such as textile designers, dancers and movement artists.

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The novel textile-embodied interface described in this paper was developed in close collaboration between a sonic interaction designer (Madaghiele) and an interactive textile designer (Demir). The artifact is called Pain Creature and it was designed as part of the doctoral project of the second author, in which she explores the possibilities of interactive wearable textiles to facilitate somaesthetic awareness of pain through explicating its qualities [11]. To promote somaesthetic awareness, the artifact mediates auditory-touch-movement interaction promoting improvisational engagements. In the context of the second author's PhD project, the artifact is defined as a *soma extension* that provides self-reflection regarding pain. In addition to being a self-reflective tool, the artifact is employed as part of an improvisational dance performance that was developed by the two authors of this paper. In the performance, the second author enacts the experience of pain wearing the artifact, while the first author generates an electronic sound accompaniment.

Respectively, this paper discusses how the collaboration between the two authors generated the design of the embodied instrument and its use in performance. The contributions are: (i) the description of the design process, (ii) the technical description of a novel textile-embodied interface and (iii) reflections on how interdisciplinary collaboration affected the design of the instrument and its use in performance.

2. BACKGROUND

2.1 Conceptual framing

Pain is an agonizing bodily phenomenon that is inevitable; for many unfortunate ones pain is chronic, thus, it is part of their bodily existence. Pain is often seen as a strong physical disturbance, yet its connection to one's psychological being should not be overlooked. In this project, pain is considered as an embodied phenomenon that is entangled in our somatic existence. In other words, the experience of pain alters one's understanding of self and the world. In phenomenology, the body is discussed as the source of perception and meaning-making processes [43, 24]; through our sensing and moving bodies we can develop new bodily 'I cans' in a constant flux of movement [50].

Somaesthetics argues that improving our somatic - sensory bodily - knowledge may lead to finding ways of living better lives in harmony with our bodies [51]. Body awareness in the context of somaesthetics considers heightening consciousness of bodily sensations and actions for better self-use. In this work somaesthetics is interpreted to sharpen bodily consciousness regarding pain, to flourish new bodily understandings and self-caring practices. In other words, Pain Creature - as a soma extension - supports people to reflect on and develop new living practices about how they exercise, undertake daily mundane tasks, socialize, etc. with their bodies in pain. At the same time, the performance of Pain Creature, which is also presented in this paper, portrays one of the many ways of moving, living, and being in pain. In the performance, the second author whose movement capabilities were influenced by chronic pain continuously discovers new bodily 'I cans' through improvisational movement mediated by the artifact.

2.2 Embodied musical interfaces

Embodied interactions [16] have been the subject of several studies in HCI, with many application to music and instrument design [60, 7]. Musical embodied interactions have been explored in different ways, for example through real-time sonification of biodata [20, 14], sonification of movements [22], or mediated through wearable artefacts such as interactive costumes [36] and prosthesis [29]. Several sensing methods are available when designing embodied Digital Musical Instruments (DMIs) [42], such as electromyography [21], accelerometers, gyroscopes and flex sensors [54]. Among these, the use of direct sound from microphones can lead to interesting and complex sonic results. An example of this technique is the work of Donnarumma [14, 13], in which direct sound from the body, recorded with condenser microphones, is used as a material for movement sonification [13].

Recent advances in fabrication techniques and sensing methods [33, 46] allowed interactive textiles to be employed in several musical applications, for example as malleable objects used as musical controllers [15] and to develop wearable costumes for interactive dance [53]. In the first case, the stream of data generated by sensors that detect deformation of the textile material is used to control musical parameters. Relevant examples include the FabricKeyboard [45], the Embroidered Musical Ball [58], the felt sensors by Grant [26], foamin [57] and the Zstretch audio controller [8]. In the second case, interactive textiles are used to sense movements in dancers and/or gestural information in performing musicians. The gestural data collected by the interactive textiles is used in these instances to generate control information for sound synthesis [9, 36, 18, 52, 47, 17] or to affect the sound processing of the instrument being played [49, 61]. Other applications of interactive textiles include displaying information through audiovisual cues [3] or incorporating actuators to augment the performance experience of the musicians [10, 6] and the audience [34] through haptic feedback.

In our previous work, we have investigated the use of contact microphones as sonic interaction devices embedded in textile garments in two experiments, focusing on the sense-making process of such interfaces [39] and at their use in real-time data sonification [38].

2.3 DMI design methods

In this paper, we focus on the collaborative side of our design process. The design process of DMIs is the subject of substantial research attention in the NIME community. Collaborative approaches such as participatory design [23], pedagogical [55], and practice-based methods [27] have been employed to involve non-musical practitioners in different stages of the design process. Collaborating with practitioners who are experts in artistic areas such as textile design, movement and dance has been a way to explore material properties and develop DMIs with novel qualities [40]: Stewart [53] points out that e-textiles can provide sofistication and nuance in computational audio applications, and Armitage et al. [1] found that subtlety and detail in instrument design can emerge from close contact and experimentation with materials. This is also reported in Zeagler et al.'s analysis of cross-disciplinary collaboration in the design of a wearable musical instrument [62]. Additionally, collaboration with non-musical practitioners can provide novel designs on a conceptual level, inspired by the experience of their specific artistic practice [4].

In this project, we employed soma design [31], a first-person design method [32] used to design embodied interactions. Soma design offers a theoretical framework and set of methods that can leverage the expressiveness and aesthetic qualities of bodily phenomena and design materials. In soma design, the design process starts with the designers' first-person bodily exploration to gain insight into the bodily phenomenon that they explore to inform the design. To cultivate subjective bodily insights designers can engage with somatic practices i.e., yoga, Feldenkrais, dance, etc., or turn mundane activities like walking strange through slowing down [31]. This is also referred to as unhabitual movement engagements [12], moving and making strange [37], and estrangement [59] in embodied stances of design. Soma design has been previously used in the NIME community by Cotton et al. [10], Martinez-Avila et al. [41] and Bang et al. [2] for the development of embodied DMIs.

3. DESIGN PROCESS

Chronic pain is a persistent bodily event that is not experienced the same way every day; the intensity or the quality of it changes. Hence, Pain Creature aims to cultivate the various temporal qualities of pain to inform the creation of the soma extension. The design process of Pain Creature unfolds in two phases: 1) somatic exploration and 2) material exploration. The somatic exploration phase unfolds as the first-person exploration of the second author where she cultivated her lived experiences of pain to inform the design of the soma extension. The material exploration phase is a collaborative process between the two authors that resulted in the making of the soma extension. The in-depth explanation of this multi-layered design process can be found in the second author's dissertation [11]. In this section, we provide a brief overview of this two-folded design process as a background for our collaborative making.

3.1 Somatic exploration: autobiographical design process

The second author is a woman who experiences chronic upper back pain and she is also a somatic practitioner, specifically, a certified yoga instructor and an improvisational dance practitioner. Accordingly, the somatic exploration phase started with the second author's improvisational dance experiment where she moved by listening to her pain and generating visual-textual documentation of her experience for a week. She video-recorded each session and noted down some keywords describing her felt experiences during these sessions. Upon the completion of the week-long experiment, she rewatched her video recordings to capture still images that represent the keywords. To make sense of the visual-textual documentation, she applied a process similar to thematic analysis [25] to articulate different qualities of pain, hence, she gleaned six temporal qualities of pain.

Figure 1 represents the visual mappings of these six pain qualities 1) Burden, 2) Tectonic Plates, 3) Waves, 4) Warm Touch, 5) Flesh, and 6) Empty. Burden reflects the heaviness of pain and its massive existence in the body; Tectonic

Figure 1: Visual maps developed by the second author as part of the autobiographical documentation process. The qualities of pain are identified and represented in six different groups: (1) Burden, (2) Tectonic Plates, (3) Waves, (4) Warm Touch, (5) Flesh, and (6) Empty.

Plates symbolize the shifting movements of painful parts of the body; Waves is closer to the relieving aspects of pain representing the lightness of the body free from pain; Warm Touch illustrates the feeling of a companion that cares for the body in pain; Flesh embodies the strong contacts of bodily materials i.e., muscles, ligaments, and bones; finally, Empty signifies the body in pain as a disconnected embodied being.

After formalizing the pain concepts that will be used to inform the design of the soma extension, the second author prepared a table ideating on the textile and auditory qualities of each pain concept that was shared with the first author, together with the body maps during the material exploration phase. The keywords used to describe the qualities of pain are collected in Table 1.

Table 1: Dimensions of pain and their respective keywords as reported in the auto-ethnographic textual documentation.

Dimension of Pain	Keywords
1. Burden	Heavy, Cumbersome, Rough
2. Tectonic Plates	Gear Wheels, Mechanical
3. Waves	Flow, Exploration
4. Warm Touch	Contact, Soft, Gentle
5. Flesh	Entangled, Ripping
6. Empty	Body, Disconnected

3.2 Material exploration: collaborative design process

Upon the completion of the somatic exploration phase which was developed independently by the second author, the material exploration phase started where both authors collaborated on the making of the soma extension. This phase started with the second author's presentation of pain concepts to the first author using body map drawings and keywords as a way to transfer her bodily experience of pain. The aim of this phase was to create the physical manifestation of temporal qualities of pain through the use of textile and auditory materials.

The making process unraveled iteratively where both authors were in constant communication and negotiation; the sound designs were developed uniquely by the first author, and the textile designs by the second. However, textile and sound design influenced each other. Textile materials were chosen based on their sonic properties and their visual-tactile qualities. The sonic properties of textile materials were then employed creatively in sound design. In addition to the traditional textile materials such as wool, cotton, or polyester mix yarns, based on the negotiations with the first author, the second author used non-traditional materials to support the sound design.

Figure 2: The Pain Creature artifact. The six dimensions of pain identified through somatic exploration are expressed in the material exploration phase through five textile arms with different visual-tactile-auditory qualities. Photography by Kadri Tiganik.

The sounds of different materials were recorded using contact microphones and processed on a computer in Pure Data (PD) [48], and they were later transferred on a Bela Mini embedded platform [44]. While adapting the sound designs developed on the computer to run on Bela, it was necessary to eliminate one of the pain concepts because the sound design was taking up extensive memory space on the Bela causing flaws. Since the second author's doctoral project is about externalizing pain, the Empty dimension was excluded. The process of experimenting with materials, interactions, and sound designs was repeated multiple times until a satisfactory result was reached. The final result is the Pain Creature artifact that is worn on the body, representing five concepts of pain through different visual-tactile-auditory qualities.

4. IMPLEMENTATION

4.1 System Design

Pain Creature is a wearable artifact that is worn on the back. The definitive version of the artifact is shown in Figure 2. It consists of one large centerpiece and five different components - interactive arms - that are connected to the centerpiece. The centerpiece encompasses electronics and it is made of a felted polyester-wool mix fabric to carry the electronic without sagging. Five interactive components are made of various textile materials and they represent the five distinct qualities of pain (see section 3.1)[1].

The center piece contains a Bela Mini [44] with a Multichannel Expander, which allows for connecting up to eight audio inputs and eight audio outputs to the Bela. Five piezoelectric disks used as contact microphones are connected to different audio inputs of the Bela, one for each textile arm. The contact microphones are connected to the Bela audio inputs via a 3.5 mm mono jack; the piezo discs of each arm can be disconnected individually, such that the disconnected arm remains silent. The sound output of the Bela can be listened to from the stereo minijack output of the Bela with headphones or connected to speakers through a wireless transmitter. The Bela and the jack plugs are fixed to the centerpiece using custom-designed 3D printed cases, which were stitched to the fabric, as shown in Figure 3. The centerpiece also stores a battery power bank to power the Bela during usage.

Figure 3: 3D printed cases storing the Bela and the 3.5mm jack connections inside the centerpiece of the artifact. The cases are stitched to the centerpiece, securing the Bela and the jack connections from abrupt movements.

The contact microphones are used both as a source of sonic material and as touch sensors. A synthesis model is associated with each textile arm, coded in PD, and run on the Bela. Each synthesis model takes as input the sound from the contact microphone in the respective arm and processes it using different sound design techniques. The amplitude of each synth sound at any given time is controlled by an envelope follower applied to the respective piezo sound, such that the arm is silent when it's not touched.

4.2 Textile arms

The second author designed five different textile arms, one for each dimension of Pain described in Table 1. For each of the textile arms, the authors experimented with how length, shape, material and touch qualities affect the sonic interaction strategies, inspired by the documentation described in Section 3.1. A signal flow diagram of the instrument is shown in Figure 4. In this section we describe the design of each of the arms:

Burden. This arm represents heavy, cumbersome, rough qualities of Pain. It is made of two parts: 1) the main body part that is tightly knitted with a light pink elastic and grey thin polyester yarns and 2) the end part that is knitted with paper yarns. The piezo disk is stitched to the paper section, it records the rough sound of the paper in contact with the body. The paper sound is processed through an adaptive sample-crushing effect to produce a heavy, distorted digital sound. This arm stimulates forceful, slow interactions.

Tectonic Plates. This dimension of pain is characterized by deep and slow, violent evolution. The arm is made of intricately intertwined ropes of grey and light pink colors. A small woven sack is attached to one of the ropes. The sack contains lentils and the piezo disk is woven inside it. The disk records the sound of the lentils moving as the arm is touched, providing a scattered sonic texture. This sound is processed through a low-pass filter and added to a noisy low-frequency FM synthesizer which is then ring modulated with a square wave. The performer can interact with this arm by strongly pulling it and by fiddling with the lentil sack.

Waves. This is a soothing, flowing expression of pain. It is characterized by slow exploration and liquid movements. The arm is composed of a long white tube connected to a shorter blue one. Both tubes are made of a knitted structure filled with a spongy material. The contact microphone is inserted at the end of the longer tube. In this tube the piezo sound is only used as a touch sensor, to control the volume of a slowly modulated additive synth, to which a low-passed noise is added. The additive synth is composed of several sine wave oscillators tuned to harmonics of 50 Hz, whose amplitudes and central frequencies are modulated by several low-frequency noise oscillators. This produces a continuous, slowly evolving sound.

Warm Touch. This arm represents pain as a mild companion, a soft, gentle presence. It is made of a long empty knitted white tube at the end of which a big element is attached, made of a lump of wadding. Inside this big soft lump, there is the piezo disk. The piezo sound is used here to modulate a phase distortion synthesizer, which is then processed through a resonant filter to produce a warm, soothing sound. The lump encourages gentle and nuanced slow touch.

Flesh. Pain is represented here as a stretching, ripping fleshy entity. It is identified in muscle tissues and bloody, watery components. This arm is made of thick red yarn to which lumps of red, orange, and pink yarns are connected. The piezo disk is inside one of the lumps. Pulling and touching the arm triggers the sound of an anharmonic FM synthesizer[2], which is combined with a squishy sound produced by a slowly modulated square wave filtered at random

[1]An example video of Pain Creature in use is available at https://zenodo.org/records/11047674

[2]The anharmonic FM synth is described in the PD documentation F11.anharmonicFM

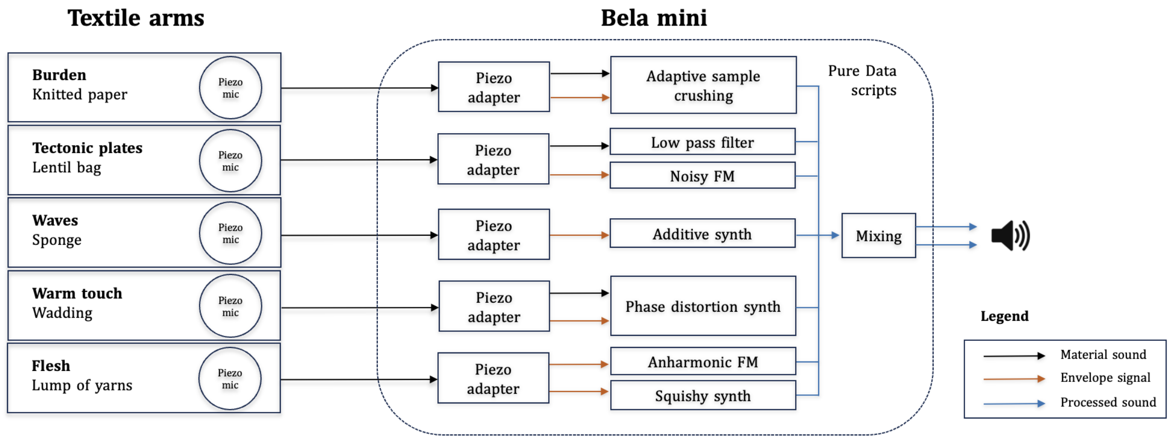

Figure 4: Signal flow diagram of the Pain Creature instrument. When a textile arm is touched, the sound of the corresponding contact microphone is processed through the respective synthesis algorithm. The piezo adapter is a PD abstraction that allows to tune the sensitivity of each piezo microphone according to the material and the sound model. The adapter amplifies the signal according to a predetermined sensitivity value and it extracts the signal's envelope, as described in [39].

frequencies. The sounds and shape of the arm encourage a strong pulling interaction.

The piezo microphones react differently to each material, this requires tuning the signal in PD independently for each of the arms. The sensitivity of each microphone was adjusted using an arctangent function as in [39], and a silence threshold was set for each of the arms. Moreover, the design of the artifact implies that more than one arm can be used at the same time. This required tuning the frequencies and mixing the volumes of the synthesizers to orchestrate the sound design as they play together.

The sound models were initially prototyped on a computer, however, the resulting sound designs were too computationally expensive to run in real-time on a Bela as they were. Therefore, the original sound designs were simplified: it was necessary to increase the block size on the Bela to 256, modulation signals are shared among the different sound models as much as possible, and pre-compiled wavetables are used instead of generating each oscillator signal individually[3].

5. PERFORMANCE

An interactive dance piece was developed as a collaboration between the two authors. The performance involves a dancer (Demir) moving on stage with Pain Creature, and a musician (Madaghiele) generating an additional layer of electronic sounds in real time. The additional electronic sounds are generated from a PD patch on a computer, and controlled through a MIDI interface. The piece premiered at Vent Space Gallery in Tallinn (Estonia) and it has an approximate duration of 20 minutes[4]. Pictures from the performance are shown in Figure 5.

The structure of the performance is composed of four main sections, each characterized by a different live electronic accompaniment, during which both performers have room for improvisation. In the piece, Pain Creature acts as a complementary actor, a parasite who lives on the body of the dancer. Throughout the performance, the dancer explores her relationship to the parasite. The four stages are inspired by the second author's account of her experience of pain:

1. **Discovery:** The performance starts with the dancer lying on the ground, wearing Pain Creature. The dancer slowly moves to a background of repetitive, cascading click sounds. The purpose of this phase is introducing the interface to the audience, presenting the movement-sounds relationship. This section represents the performer discovering her pain.

2. **Conflict:** Once the pain is discovered, the performer struggles to accept it. Her fight with pain is depicted by snappy movements and a background of crushing distorted synthesized kick drum sounds.

3. **Understanding/Exploration:** After fighting pain, the performer changes her approach and treats it gently, exploring and understanding it. This section is a solo of the dancer with Pain Creature, with no additional electronic sounds. Here she plays with each arm individually, unveiling the distinct interaction mappings to the audience. This section represents understanding and making peace with pain.

4. **Disruption/Iteration:** The last section disrupts the dancer's acceptance of pain; in this section the Pain Creature sounds are distorted in real-time through overdrive and feedback. The dancer, who thought she had finally understood pain, cannot recognize it anymore, and she has to start the difficult exploration process once again.

6. DISCUSSION

6.1 Negotiation between expertises

Dialogical communication between materials and techniques of textile and sound design led to distinctive interaction qualities for each arm of Pain Creature. Using contact microphones to record the real-time sound of the textiles allowed to closely connect material properties to sound designs. A material's sonic response can affect users' perception of it [35, 30], therefore the sound designs have a complementary function to touch, inviting or discouraging certain ways of

[3]The PD code running on Bela is available at `https://zenodo.org/records/11047599`

[4]A video excerpt from the performance is available at `https://zenodo.org/records/11047691`

Figure 5: Pictures from the premiere of the Pain Creature performance at Vent Space Gallery in Tallinn (Estonia). Photography by Kadri Tiganik.

interacting with the artifact. For example, a longer decay can invite a gentler touch, while a faster sonic response can encourage more abrupt interactions.

These negotiations between interaction modalities resulted in a series of peculiar interaction strategies, such as the small bag containing lentils in the ***Tectonic Plates*** arm, which provides an engaging tactile experience as well as an interesting sound source. This arm was inspired by the first author's experimentation with granular synthesis using the lentils as a sound source, which was then adopted in the material design by the second author. In the final version of the artifact, the granular synthesizer was abandoned, however, the bag of lentils was maintained as an interaction element and a sound source. Another instance is the interaction technique in the ***Burden*** arm. This arm is based on the second author's experience in knitting paper yarns. The rough paper surface suggests an energetic touch, providing a sound source with short attacks and rich high-frequency responses. Processing these sounds through sample-crushing complements and invites such forceful interactions, resulting in a harsh and scattered sonic response, with a fast decay. A similar strategy was used in the ***Flesh*** arm. Here the objective was stimulating a strong pulling interaction, therefore the piezo microphone was incorporated inside a lump of threads which would produce louder sounds as the arm was pulled. To encourage pulling, louder sounds were mapped to increased intensity of the *squishy* synth and a higher degree of frequency modulation.

6.2 Performing with Pain Creature

6.2.1 Sonic interaction design

The main focus during the design of the interface was on movement improvisation, aiming for an intuitive, immediate response of sound to touch. For this reason, explicit musical parameter controls have not been integrated into the artifact, limiting its possibilities of sonic variations. As expected, this allows the performer to focus on movement improvisation while still shaping the sounds intuitively in real time. However, this aspect can be a significant limitation when performing, since the sound designs are relatively static and they leave few opportunities for conscious control of musical properties to the dancer. This means that in performance the Pain Creature sounds need to be integrated with an accompaniment of additional electronic sounds, otherwise the sonic aspect of the piece can be perceived as too repetitive for an act of medium-long duration.

6.2.2 Gesture-to-sound interpretability

In the piece, the artifact is presented as a materialization of the dancer's pain, a mysterious physical entity that communicates through abstract sonic responses. A crucial aspect for the narrative of the piece is the ability of the audience to distinguish the sounds emitted by the artifact in relation to the dancer's movement from the sounds that are introduced as an accompaniment. This is a habitual concern when presenting any novel DMIs to an audience [19], as the interpretability of gesture-to-sound mappings is a fundamental component of a musical performance; in this case, this is specifically relevant since the artifact undertakes a narrative role in the piece. It was not possible to investigate the degree to which this distinction was understood by the audience within the scope of this paper, however a future study with audience interviews could provide interesting insights for the development of new interactive performances of this kind.

7. CONCLUSIONS

This paper presents a novel textile-musical interface for improvisational dance and sound-making. Pain Creature was designed as a collaborative work between a sonic interaction designer and an interactive textile designer. The paper describes the design method employed to develop the instrument, the techniques that were used for tactile interactions, and the performance strategies employed in an interactive dance piece.

Overall, Pain Creature provides a successful example of collaborative work between practitioners of different artistic disciplines, deeply integrating expertise from textile design, sound design, and improvisational dance. The interface provides interesting possibilities for improvisational movement, self-exploration, and self-expression through sound making. Future work could entail researching interpretability through audience interviews and further integration of musical parameters in textile interfaces, investigating how to increase user control over the sonic material without sacrificing intuitiveness.

8. ETHICS STATEMENT

This project is part of Arife Dila Demir's PhD research, funded by the Estonian Academy of Arts (EKA). The development of the Pain Creature performance was partially funded by Nordic Culture Point through the Nordic Mobility Program (MOB2303), and hosted at Vent Space Gallery in Tallinn (Estonia). The code developed for the project is released as open-source software, guaranteeing reproducibility. No human participants have been involved in the research besides the second author. No conflicts of interest are reported by the authors.

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