FROM SONIC GESTURE TO COMPOSITION: MAPPING THE PATH FOR THE PHYSICAL COMPUTING INSTRUMENT

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ABSTRACT

As a composer and multi-instrumentalist, I use the studio as a tool for real-time performance and composition. In recent years, this process has suffered constraints due to my need to incorporate more studio elements to produce and manipulate sound. My research project seeks to address these challenges by developing and mapping a digital musical instrument – the Physical Computing Instrument (PCI) – that uses gestures to produce sound.

In this paper, we delve into recent developments in our research, exploring three gestural Digital Musical Instruments (DMIs) as exploratory tools for refining the PCI's design and functionality. We focus on the musical challenges arising from it, encompassing idiomatic writing, notation, and performance, and how these aspects contribute to the PCI's development, clarifying its scope and identity, while establishing a systematized approach for its practice.

Additionally, the paper introduces two original compositions, accompanied by notational sketches and mapping strategies tailored for these gestural controllers. These elements provide valuable insights into the prototyping of the PCI, showcasing its potential applications.

1. INTRODUCTION

My artistic practice hinges on performance as a real-time composition process, where movement and gesture convey instrumental meaning [1]. The music I craft is intrinsically tied to instrumental performance. It is the performance of sound that leads me to composition. This process makes use of traditional, analog, and digital instruments, as well as microphones, sensors, DACs, MIDI interfaces, and notational software, promoting the interaction of elements to favor sound-based composition. This dynamic process has suffered constraints due to my need to augment the studio with more elements to produce and manipulate sound. By constraints, I allude to the growing challenge of maintaining the immediacy of what Van Nort aptly termed "action-sound coupling" [2]. To surmount these constraints, I propose the introduction of the Physical Computing Instrument, an addition to my studio and my live performances. The PCI is envisioned as an instrument that generates sounds and seamlessly connects and interacts in real-time with existing studio elements. The PCI will be a sound-producing device that can be controlled by a variety of physical gestures and is reactive to user actions [3].

One of the main challenges regarding the creation of a digital instrument with gestural control is the establishment of the artificial relationships that govern sound production and its control. As d'Escriván points out, this is a novel frontier with contours yet to be fully defined [4]. Jordà states that a new instrument must be capable of shaping thinking, relations, interactions, and temporal and textural organization, ultimately leading to the emergence of new kinds of music [5]. If challenges are extended to immersive visual and sonic environments, there is also a need to address the rich and autonomous ecosystems within these environments, as Hamilton has pointed out. These ecosystems have their own rules and realities that can impact user interactions [6].

The challenges extend to notation, as there is no standardized system for these new instruments. Thus, in the DMI domain, notation could be embedded in the instrument. As Thor Magnusson points out, pieces could end up having a notation that is not specific to the instrument but refers to the type of mapping it needs [7]. Notation beyond its intrinsic value – a code to compose and to perform – could serve multiple purposes, including acting as a design constraint for new digital instruments, as it can lead to a systematization and instrumental practice. Moreover, a written repertoire both for solo and ensemble contexts may improve the DMI's longevity while attracting a broader community [8]. In that context, the PCI seeks to achieve a dynamic relationship between its physical affordances and idiomatic notation to scale up its full potential as a tool for new repertoire. It is also intended that this new repertoire could be written without the need for special vector graphics software, instead using readily available symbols in standard notation software like *Finale* or *Sibelius*.

Moreover, the PCI is designed to be accessible to non-specialized practitioners who may not be familiar with technology but are eager to expand their artistic horizons. It must be user-friendly and feature notation that is easily comprehensible, leveraging symbols and layouts familiar to practitioners. It features a gentle learning curve, portability, and the capability to augment existing instruments. This aspiration aligns with the design principles of acoustic instruments, considering factors like ergonomics, range, expressiveness, instrumental gestures, durability, and mapping choices [9].

To illuminate these concepts, I employ three gestural controllers as probes – the Leap Motion V.1, an optical hand-tracking module that captures the intricate movements of hands and fingers; Wii Remote & Nunchuck Motion Plus, the primary controllers for the Nintendo Wii, and Myo Armband, a gestural armband that reads biosignals (Electromyographic signals – EMG) and remotely connects with other devices. In the following sections, I will present two compositions: "Tiny Oracle for Wii Remote and Leap Motion", and "Tiny Oracle for Solo Flute and Myo Armband". These compositions exemplify how these gestural controllers serve as valuable research tools, paving the way for the implementation of the PCI and the development of idiomatic notation.

2. CONTEXT

Central to my artistic research is the use of timbre as a fundamental compositional tool. Given my focus on sound processing, synthesis, and the creation of non-acoustic sounds, the instrument I aim to construct falls within the domain of Digital Musical Instruments. The *Physical Computing Instrument* consists of two primary elements: a gestural controller and a sound generation unit. The gestural controller, or gestural interface, will manage and transmit data encoding both performer actions and composer intentions. It will incorporate an array of sensors, including bio-signal sensors (such as electro-myographic), motion tracking sensors (infra-red, Nine degrees of freedom – 9DoF), haptic sensors, and wireless sensors for seamless data exchange between the two units.

All this information will be mapped into a sound generation unit, the second element of the instrument, and decoded in a MaxMSP patch. Beyond sound generation and the mapping of bodily parameters, this patch will facilitate communication with studio elements (such as DAW, analog synthesis, and signal processing), expanding the instrument's possibilities. Given its highly technological nature, collaboration with the Department of Materials and Ceramics at the University of Aveiro (CICECO) has been sought for the implementation and construction of the instrument as well as the Institute for Systems and Computer Engineering, Technology and Science (INESC TEC).

The current stage of the *PCI* implementation comprises the following items:

- Gestural Implementation through existing DMIs: *Leap Motion*, *Wii Remote*, *Myo Armband.*
- Pieces and compositional sketches, combining the three DMIs and traditional instruments.
- Study of mapping possibilities and signal acquisition.
- Construction of a prototype.
- Notational studies.

An initial concept sketch of the instrument is provided in Figure 1.

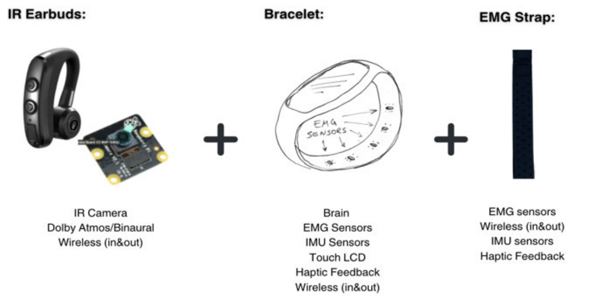

Figure 1. Physical Computing Instrument (Sketch)

The PCI comprises three essential components: IR Earbuds, a Bracelet (the brain), and an EMG strap. The infrared (IR) earbuds offer versatile practical applications, serving as a component in tracking hands and finger movements. As an example, it can be employed to train models that will assist a performer in changing parameters like sounds and patches remotely, providing additional layers of musical expression. We are testing this possibility using Machine Learning (ML) software like *Wekinator* or *ml.lib* a cross-platform for MaxMSP and Pure Data [10, 11]. Additionally, ML models could be used to facilitate remote page turning in digital readers, freeing performers from the constraints of physical scores or using trigger pedals for that function.

Another feature of the earbuds is the spatial capabilities, decoding 360º formats, propelling the PCI into the realm of real-time performance and composition within a 3D environment. This feature transforms the instrument into a versatile tool for both studio work and live performances, given the provision of a spatial system. A simple arm gesture (using the inertial movement unit – IMU at the bracelet) becomes a conduit for directing sound to any desired point in a room, enhancing the spatial dynamics of the musical experience. This real-time feedback mechanism not only enhances the performer's control over the spatial aspects of the performance but also ensures an immersive and precisely orchestrated auditory experience.

The bracelet itself is designed to be a comprehensive control center for the PCI. Linked wirelessly to the earbuds and the EMG Strap, allows the mapping of the performer's arms, hands, and fingers. It also integrates an LCD touchscreen that serves as an intuitive interface. This touchscreen enhances the accessibility of the instrument's features but also provides real-time visual monitoring of its operation. The inclusion of this visual element minimizes the reliance on external devices, effectively mitigating the need for a laptop during performances.

3. DMIs AS PROBES

None of the three interfaces that I chose as a research path for the PCI's implementation were conceived as musical instruments. However, their latent potential has been harnessed and expanded upon by the NIME (New Interfaces

For Musical Expression) community. Its mapping contained gaps that led to the implementation of alternatives for its use in music, such as the *Myo mapper* or the Myo-to-Osc developed for the 'RAW' instrument, a platform for collective performance [12, 13]. Similarly, the *Leap mapper* app is designed for the *Leap Motion* [14].

The three gestural controllers operate on distinct technologies, providing diverse mapping and feature possibilities. These and other software alternatives facilitate communication into various protocols such as MIDI or OSC for practical application with the interfaces at my studio [15]. Next, I'll show two compositions that exemplify how these gestural controllers are being used as valuable research tools, paving the way for the implementation of the PCI and the development of idiomatic notation.

3.1. Tiny Oracle – For Wii Remote and Leap Motion

Tiny Oracle for Wii Remote and Leap Motion (2023)[1] is the first piece that I wrote within the scope of the research. The sound materials result from 20 prepared piano samples processed with granular synthesis, pitch, and phase shifting techniques.

Figure 2. Recording Setup at DECA's Studio (INET/md)

Although I didn't write it using the two DMIs – I used a MIDI keyboard – the musical gestures were performed having in mind the affordances of the *Wii remote* and the *Leap Motion.* After writing the piece, I started the implementation of the piano samples in the *Wii Remote* and the *Leap Motion* using *OSCulator*, *Leap Mapper*, and an *EX24* soft sampler.

The implementation consists of mapping the sounds to be playable by the gestural controllers and inferring if their affordances are satisfactory from the performer's point of view [16]. The refinement of performance expression, technique, and ergonomics becomes a focal point during this stage.

Questions surface organically, steering the exploration towards the heart of artistic feasibility, such as "Is it possible for these frugal interfaces to interpret and perform the piece effectively?" and "Can the sounds produced by these controllers be accurately represented in a musical score?"

/hand1/pinch	MIDI Note	F#1
/hand1/position	–	–
0	MIDI Note	C0
1	MIDI Note	G1
2	MIDI Note	C3
/wii/1/accel/pry	–	–
0: pitch	MIDI CC	1
1: roll	MIDI CC	1
2: yaw	MIDI CC	2
3: accel	MIDI Note	G#1
/wii/1/button/1	MIDI Note	F#1
/wii/1/button/2	MIDI Note	C#1
/wii/1/button/A	MIDI Note	A1
/wii/1/button/B	MIDI Note	D1
/wii/1/button/Down	MIDI Note	F2
/wii/1/button/Home	MIDI Note	C1
/wii/1/button/Left	MIDI Note	F1
/wii/1/button/Minus	MIDI Note	F3
/wii/1/button/Plus	MIDI Note	A0
/wii/1/button/Right	MIDI Note	F0
/wii/1/button/Up	MIDI Note	D0
/wii/1/nunchuk/accel/pry	–	–
0: pitch	–	–
1: roll	–	–
2: yaw	–	–
3: accel	MIDI Note	A3
/wii/1/nunchuk/button/C	MIDI Note	C5
/wii/1/nunchuk/button/Z	MIDI Note	C#0
/wii/1/nunchuk/joy	–	–
0: x	MIDI Note	C6

Figure 3. Sampler mapping using OSCulator

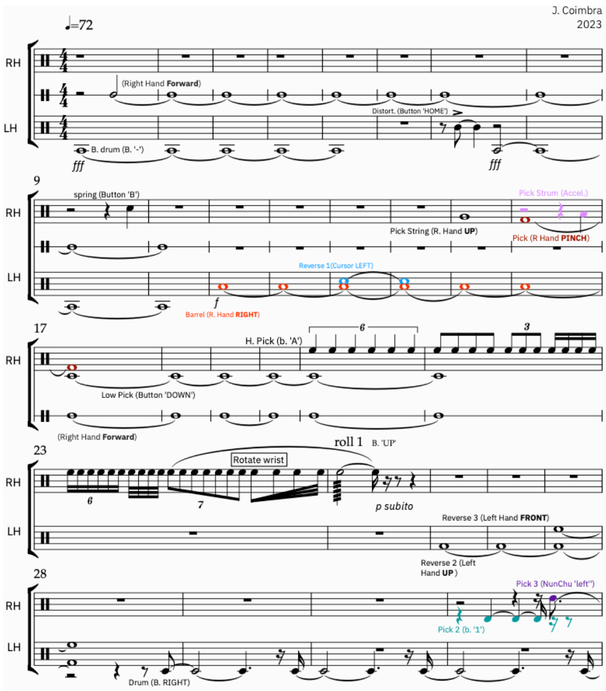

Figure 4. Tiny Oracle for Solo DMI (excerpt)

For notating *Tiny Oracle for Wii Remote and Leap Motion V.1,* I opted for a grand staff with a percussion-based stave in between. I spread the high register samples at the upper stave (right hand) and the low register samples at the below stave (left hand). The performer uses both hands to control the gestural controllers.

[1] A sound file of the piece it's available under: https://on.soundcloud.com/yr1mt

The percussion-based stave was intended to notate the triggering of a specific sound, using neck and wrist rotation (for a continuous manipulation of timbre), but that proved impossible to map with these controllers. The idea was to free the hands to the sounds that demand a rhythmically precise performance and use the neck to trigger sounds that change over time and that aesthetically work as a sound metaphor for the human body, specifically the cervical vertebrae [17].

As an alternative, I have mapped that specific sound to be triggered by *Leap Motion* with the instruction "Right Hand Forward" (see Bar 1 in Figure 4.).

Figure 4 visually articulates the distribution of samples across the grand staff and the percussion-based stave, illustrating the thoughtful design considerations made to navigate the unique challenges posed by the gestural controllers. Additionally, colored note-heads have been used to check if it helps in memorization.

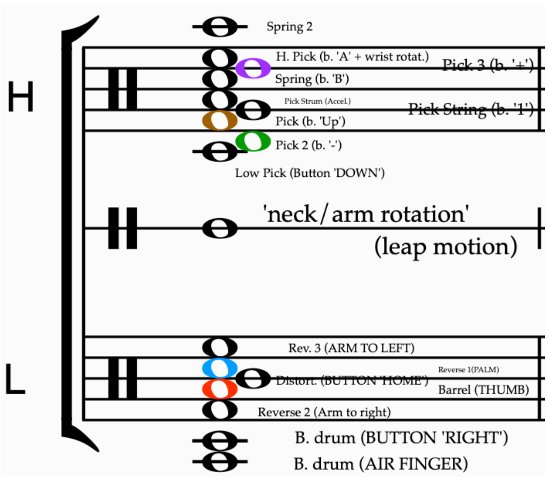

Figure 5. Tablature

I played the piece live recently. The choice of a traditional grand staff, despite not correlating with precise pitch, helped as a practical approach to score memorization [18]. Even in the absence of a direct correspondence between symbol and pitch, the arrangement of samplers by the register in a traditional score provided a mnemonic aid. This structuring also enabled the precise notation of rhythm, aligning with the demands of my sound-based composition [19]. I played the piece using the following setup: *Wii Remote*, *Nunchuck*, *Leap Motion*, *Osculator*, *Leap Mapper*, an *EX24* Sampler, a laptop, and a *DAC* interface[2]. I then did an improvisation piece using the same setup plus a *soft synth*, and an amplified cymbal. It was surprising to witness how these frugal interfaces effortlessly conveyed significant instrumental meaning through the expressive movements and gestures they enabled.

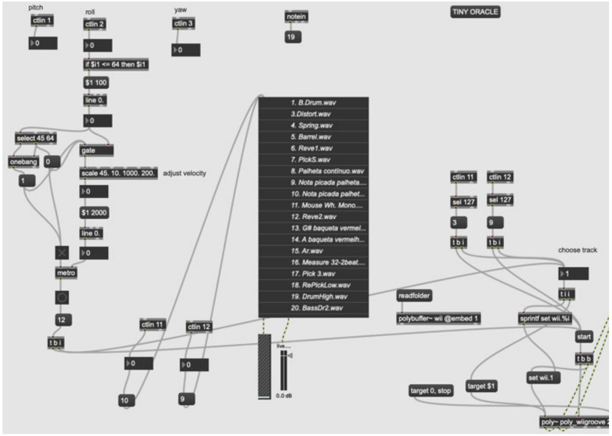

Figure 6. Tiny Oracle MaxMSP implementation

Figure 7. Performance at jornadas CICECO'23

We're already implementing the piece in MaxMSP since it will be the platform chosen for the prototype due to its mapping flexibility.

3.2. Tiny Oracle – For Flute and Myo Armband

Tiny Oracle for Flute and Myo Armband[3] is an adaptation of *Tiny Oracle for Solo Flute* a commission for the "Frederico Freitas Award" of Aveiro University. Again, I didn't write the electronic making use of the gestural controllers, but the musical gestures were created having in mind the affordances of the *Myo Armband* [20].

This piece introduces the utilization of electro-myographic sensors (EMG) and the Inertial Measurement Unit (IMU) of the *Myo* to dynamically trigger sounds. The activation of the samplers is achieved through an 'air fingering' technique, engaging the *EMG* sensors, and through the performer's movements that activate the unit's accelerometer. The captured data is then transmitted by *Myo* via *Bluetooth Le* to a computer, where the sounds are stored.

[2] A video of a rehearsal and an interview explaining the implementation of the piece is available under: https://youtu.be/Qn6SXdVpcqU.

[3] A sound file of the piece is available under: https://on.soundcloud.com/iDBzY.

The *Myo* device is worn on the performer's forearm, specifically on the right forearm for ergonomic considerations.

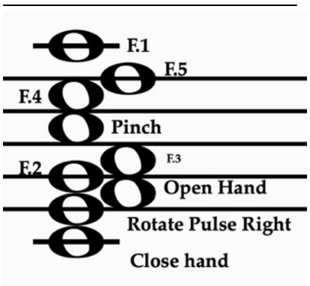

Figure 8. Tablature of Myo gestures

The score is structured with two staves, with the upper stave dedicated to *Myo* and the lower stave notating the Flute. In the context of *Myo* notation, 'X' note heads represent sound triggering, continuous control of timbral manipulation, and three-dimensional sound spatialization using *ZHDK ambisonics* externals in MaxMSP.[4] 'Diamond' note heads represent sound triggering in the vertical plane (up and down) and continuous control of timbral manipulation with spatial correlation granted by the *ambisonics* system. Standard note-heads signify sample triggering at specific points in the timeline.

The triggering of the samplers represented by standard note-heads is accomplished with gestures such as lifting fingers from the flute keys to a sufficient distance to execute the 'air fingering', opening, closing, and pulse rotation clockwise using the right hand.

Samplers represented by 'X' and 'diamond' note heads are triggered by the player's movement and make use of the accelerometer and the IMU unit of the gestural controller.

An excerpt of the score, presented in Figure 8, provides a visual representation of these notational instructions.

All samplers are programmed with 'Note In' and 'Note Off' commands, providing precise temporal control and flexibility. Taking bars 21, 23, or 29 as examples, one can observe varying durations of 'X' notes. At the same time, the samplers are subject to signal processing induced by the player's movements, resulting in timbral manipulations. 'X' and 'diamond' notes mapping not only trigger sounds but permits their manipulation during the notated musical gesture.

The mapping process is executed through MaxMSP, using the *Myo Mapper* to convert *Myo* data into *OSC* messages. Additionally, a foot pedal is employed to activate and deactivate the *Myo*, preventing inadvertent triggering.

The piece's implementation is being realized in collaboration with a flutist, who contributes valuable insights to establish a cohesive connection between the instrument, the prescribed musical gestures, and the electronic implementation. Using 'extended' traditional notation enhances sight-reading, allowing the musician to concentrate on

Figure 9. Tiny Oracle for Flute and *Myo* (Excerpt)

challenging aspects of the score while providing more time for focused practice. Mastery of this piece involves not only learning the flute score but also understanding the intricacies of the electronic setup, including *Myo*, *Myo Connect*, *Myo Mapper*, *Max* patch, and a 9-channel *DAC* for 2nd order *ambisonics*. This collaborative effort is an opportunity to familiarize the performer with the live setup system [21]. The increasing familiarity with the four elements – score, *myo connect*, myo mapper, and *MaxMSP* – will help perform the piece more easily and may lead to developing a richer, more personal musical language with which to interpret it [22]. Limiting the complexity of the score is also an auto-imposed constraint that intends to free the interpreter to interpret.

Finally, the piece deals with the interaction of the acoustics proprieties of the room/concert hall where it will be performed. The player moves on stage stopping at various spots ("Stations") and listening to the changes in sound in between. The audience is invited to listen and be aware of those changes that blend the "natural" acoustic of a particular venue and the emission of the electronic musical material provided by the *ambisonics* environment.

To conclude, using DMIs as probes allows us to assess how these pieces can be played and what is possible to do using the frugal technology provided. Thus, it elucidates how to develop idiomatic notation not only within the scope of these DMIs but also for the PCI.

[4] https://www.zhdk.ch/forschung/icst/software-downloads-5379

4. NEXT STEPS

The forthcoming phase of this research encompasses the construction of a prototype in collaboration with the Materials Department at Aveiro University (CICECO). This collaborative effort aims to synthesize the theoretical groundwork into a tangible prototype, setting the stage for further exploration and refinement.

Integral to this process is creating new musical pieces, delving into the nuances of musical gestures, technological implementation, and musical notation. Concurrently, the research into self-powered interfaces remains a focal point. In partnership with CICECO, experimentation with energy harvesting techniques is slated, exploring possibilities such as extracting energy from the human body, harnessing solar power, and capitalizing on the instrument's performance-induced vibrations [23, 24].

The research trajectory will continue to involve close collaboration with performers, engaging them in the implementation of the pieces. Furthermore, a comprehensive inquiry is underway, targeting performers and composers with diverse backgrounds. The survey navigates their relationship with technological tools in both performance and composition, encompassing aspects such as preferences between fixed-media and real-time performances, possibilities for timbre augmentation on traditional instruments, sight-reading, and feedback experiences of triggering electronic sounds through metaphorical gestures. Insights into the execution of scores with real-time electronics on stage, coupled with participants' expectations for features to be integrated into the PCI, will inform the ongoing evolution of this research.

The ultimate version of the *Physical Computing Instrument* prototype will be utilized in performances, not only for premiering new compositions with diverse ensembles but also for revisiting the mapping and, in some cases, the composition of the pieces discussed in this paper. This is necessary as certain musical gestures couldn't be fully realized with the three Digital Musical Instruments presented earlier.

5. CONCLUSION

My doctoral project aims to increase the possibilities of sound-based composition, resorting to the implementation of a new digital instrument of gestural control. The *Physical Computing Instrument* will optimize my sound-based composition as a new element at my studio while maintaining the real-time manipulation of its current elements. This instrument for sound creation through synthetic processes will be explored in the composition of several works with different instrumental formations that will help shape its features and final design.

I have elaborated on the use of existing designs of gestural DMIs such as the *Leap Motion,* the *Wii Remote*, and the *Myo armband,* arguing that their different technological characteristics could contribute to understanding the possibilities of gestural implementation, notation, mapping strategies, and other features, in the PCI's construction. I presented pieces and notational sketches that exemplified how I'm using these gestural controllers as a research path.

Future developments in the project include the construction of the PCI whose sketch was presented in this paper and several pieces and performances that will serve as design constraints, improving technological implementation, and notation, refining my gestural sound-based composition in the context of contemporary orchestration. Demonstrating the PCI's potential in different configurations of instrumental ensembles and different artistic practices through the composition and performance of novel repertoire sketches and pieces could contribute to delivering use cases to a broad community, including researchers, composers from different backgrounds, trained and not-trained musicians and to those not familiar with technology but that would like to experiment an instrument that it's intended to have a minimal additional cognitive load, that is portable, simple to use, affordable, and that could expand their artistic practice.

It is anticipated that the notation will catalyze the engagement with the Physical Computing Instrument. Using an 'extended' traditional notation whenever possible aids musicians in addressing other aspects of the score and may expedite their familiarity with it, facilitating the development of a more nuanced and personal interpretation. As already referred, the performances will play a crucial role in studying the PCI's behavior in both concert and studio contexts, yielding valuable data on the pieces, the implemented technology, and the diverse forms of interaction it generates. In this context, I would like to underscore the envisioned potential for fostering improvisation and interplay through what I term "gesture interference" between performers – a 'hyper' jam session where mutual interaction and transformation of each other's musical material occur during a performance. This could manifest, for instance, in open sections of a score or within a completely improvised piece.

Finally, this research aims to contribute to resource sustainability by employing recyclable materials and developing strategies that promote the instrument's self-sufficiency in terms of energy consumption, a quality often lost with the introduction of electrified instruments.

Acknowledgments

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