Musicians’ Initial Encounters with a Smart Guitar

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ABSTRACT
This paper presents a case study of a fully working prototype of the Sensus smart guitar. Eleven professional guitar players were interviewed after a prototype test session. The smartness of the guitar was perceived as enabling the integration of a range of equipment into a single device, and the proactive exploration of novel expressions. The results draw attention to the musicians’ sense-making of the smart qualities, and to the perceived impact on their artistic practices. The themes highlight how smartness was experienced in relation to the guitar’s agency and the skills it requires, the tension between explicit (e.g. playing a string) and implicit (e.g. keeping rhythm) body movements, and to performing and producing music. Understanding this felt sense of smartness is relevant to how contemporary HCI research conceptualizes mundane artefacts enhanced with smart technologies, and to how such discourse can inform related design issues.

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INTRODUCTION
The design of smart technology is particularly challenging when embedded in analogue objects such as musical instruments. Differently from mundane devices like vacuum cleaner robots, interactive thermostats or remote light systems, smart instruments are targeted to cohorts of people with a consolidated professional experience, and who have personal preferences on how the artefact is supposed to "behave" and feel like over time. This can in turn create friction with respect to both the role of the musician and the instrument in future performances.

In this paper, we look at a smart guitar as a particular class of smart technologies intended for professional and expert users. We focus on the narratives [25, 35] that musicians start to develop about the use of the guitar in relation to their musical skills and expertise during their initial experience with a working prototype of the guitar. Sensus [52] is an electro-acoustic instrument enhanced with sensors, actuators, and an embedded computational unit; this allows guitar players to generate and modulate sounds through various movements and bodily actions.

The data was collected during a technology trial [11] giving insights on what happens when a smart guitar encounters the practices it is supposed to support. Eleven professional guitar players explored the prototype, discussed it with the creators of the instrument, and then recounted their experience through semi-structured interviews. Initial encounters with interactive prototypes are critical as they enable us to understand the challenges experienced by those whom the technology is designed for, both by enriching our knowledge of such practices [10] and by highlighting potential disruptions in them [14].

Our narratives highlight that the musicians saw a need to reconfigure their skills and expertise to learn to play the guitar, and that mastering it would entail engaging with the agency and intelligence that they associated with its computational qualities [19, 48]. The analysis unpacks the musicians' understanding of the smart qualities of the guitar and the transformation of the artistic practices emerging from its extended use. This includes *i)* the agency of the guitar and the skills involved in playing it, *ii)* the actions entailed in playing the smart guitar, *iii)* the musicians' reflections on their current practice and their visions of how the new instrument could expand their performances. When the musicians perceived a trajectory towards an increased value in the envisaged usage, they also became more positive in their narratives around the smart qualities of the guitar. This, however, intertwined with a concern for the potential obsolescence of the digital components compared to the longevity of more "traditional" instruments — longevity here is related to the musicians' experience of using the instrument over time, rather than to the practices and processes of instrument design [38].

Our findings illustrate how smartness emerges from the interplay between the musicians' use of the artefact and their reflections about the creative practices enabled. Smartness is here a dialogical property [35] experienced and understood by the musicians in the context of their situated practices [33], rather than being conceived as a fixed, predetermined quality of the design. This framing opens up opportunities for HCI research to reconsider the basic assumptions underlying the design and use of smart technologies, particularly in professional settings like artistic performances. In the discussion, for instance, we suggest that design should put more emphasis on the skills and expertise that would have to be acquired to use new smart objects, and that this is something design should strive for, rather than portraying it as an error. Moreover, we argue that in designing for the longevity and extended use of smart objects, users should be enabled to customise, re-map and, when needed, replace digital components and their associated functionalities. We see this as part of the co-performance whereby roles and practices around intelligent objects are (re)defined and created [33]. The inclusion of digital technologies in artistic settings such as interactive and mixed-reality performances has been widely explored by HCI research [3, 20, 42, 44, 49]. A more recent body of work has investigated the design and the role of interactive technologies from the point of view of the performing artists [1, 50], also including: *i)* novel ways of playing and performing music (e.g. [22, 24, 31, 53]), *ii)* augmenting and extending existing musical instruments [4, 5, 37], and *iii)* using existing interactive technologies to assemble and create music [21]. While this work constitutes an important backdrop, this paper has a broader relevance for HCI research. We illustrate how making sense of smartness in the context of professional artistic practices, and interweaving digital and analogue materials can expand people's perception of their skills and expertise, and of the nature of an artefact. This, we argue, can shape the narratives they develop about new smart technologies and, eventually, their possible adoption and use.

RELATED WORK

This paper draws on the extensive body of research on mixed-reality and interactive performance, particularly music performances.

With the emergence of new technologies comes new possibilities to incorporate interactivity in different genres of artistic performances. Research has investigated how novel technologies can provide opportunities for audience participation [3, 13, 20, 45, 43], or to transfer live experience to a remote audience [1, 57].

More recently, the focus has been shifted to the artists' experience of using interactive technologies. The Humanaquarium [49, 50], for instance, explores the role of interactive technology in enhancing the singers' sensorial and emotional connection to the audience. In another example Barkhuus et al. [1] turn towards actors of mixed-media performances to unpack the challenges of rehearsing without interactive technology, even when the technology itself is a central element of the final performance. Here the authors particularly focus on the challenges creative teams face in adopting digital technologies, and on how directing and acting practices are adjusted to overcome them. Overall, this research is relevant as it illustrates the possibilities and challenges inherent in enabling artistic practices and how they are transformed by the introduction of interactive technologies.

Interactive Music Performance

An emerging body of work has explored the design of technology and interactive instruments for music performances. In his novel and provocative work, Unander-Scharin [17, 53] presented the design of interactive instruments to enhance opera singers' performance on stage. By incorporating different accounts of his interactive instruments in several opera performances, he created an Extended Opera space for opera singers to empower their vocal expressivity through manipulation of sound as well as through bodily interactions with the interactive instrument.

A number of studies have explored the design of musical interfaces and "augmented instruments" [37]. Such instruments extend the sonic capabilities offered by the instrument in its original version. The player of such instruments can make use of sensors embedded in the instrument to control the production of the electronically generated sounds. There have been an array of interesting and innovative instruments developed in this space, notably Variax Electric guitars by Line6 [34] which enables alternate sonic profiles through embedded processing, the ACPAD [47] and Guitar Wing [26] guitar add-ons — both providing controls on the body of the guitar for musicians to manipulate musical effects.

In academia the notion of "augmented instruments" has been explored widely within the CHI community, notably in Jorda's work on digital luthiers and on the digital augmentation of instruments [28, 30, 31]. As a result, interweaving such technologies into musical performances can create unique challenges for performers and digital luthiers. Jorda discusses [30] the notion of "intelligence" in a traditional, acoustic instrument which he regards as a quality provided by the performer while interacting with it in a real time. This quality, however, changes in those digital instruments that react and respond to the performer's actions in a more complex an interactive way, putting them in the category of "intelligent instrument". Turchet et al. [52] have provided an introduction to "smart instruments". In their work, they propose the notion of smart instruments as a class of augmented instrument. This type of instrument, they argue, incorporates embedded sensors and actuators that respond to its performer. This feature makes the instrument independent of any external computer and creates a feedback loop through haptic stimuli together with data and sound processing. Relatedly, Benford et al. [4, 5, 6] have explored the augmentation of an acoustic guitar as a technology probe to collect and, later, reveal its digital footprints in the form of digital records. The Carolan guitar was not merely investigated as an instrument, but rather as an accountable "thing" — an artefact able to map people, locations and time to the presence of the artefact over its lifetime.

Research on augmented instruments and novel music interfaces is burgeoning. While these studies focus on the design of augmented instruments and their technical possibilities, and the development of platforms for embedded audio systems such as Bela [39] and D-Box [36], our contribution focuses on the narratives that the artists develop about the smartness of the guitar, and about the potential for integrating it in their performance and music making. Initial encounters with technology are relevant to HCI as they help understanding how artists adopt technologies in the context of their practices and, relatedly, why many novel instruments are developed, but few actually appropriated to make music [29]. This enables us to advance our understanding of how artists reason about putting smart instruments into use, and how this making-sense process intertwines with a discussion of the expertise and of bodily movements entailed in playing the instrument, and of its role during live performances.

Type of Sensor	*Features*
Pressure sensor #1, #2, #3	Each sensor is mapped to trigger a single note of a synthesizer and control its volume
Pressure sensor #4	A discrete control to enable and disable a delay effect
Ribbon and pressure sensors on the body	The position of the finger is mapped to pitch bend a single note of a synthesizer. The pressure is mapped to the volume of the synthesizer
Ribbon and pressure sensors on the neck	The position of the finger is mapped to notes of a synthesizer that corresponded to the notes of each fret of the sixth string. The pressure is mapped to the frequency of the LFO (Low- Frequency Oscillator) parameter of the synthesizer
Proximity sensor	The distance is mapped to the frequency of the 'wah-wah' effect
Inertial Measurement Unit (IMU)	The tracked up-down movement of the fingers is mapped to activation of a tremolo and chorus effects, as well as to the rate parameter of the tremolo. The front-back movement is mapped to a note of a synthesizer
Switch button #1	Mapped to the change of preset: a clean sound, and a distorted sound
Switch button #2	Mapped to the triggering of six different backing tracks loops
Knob #1	Mapped to the sound engine volume
Knob #2	Mapped to the guitar preamp volume

Table 1. The sensors of the Smart Guitar.

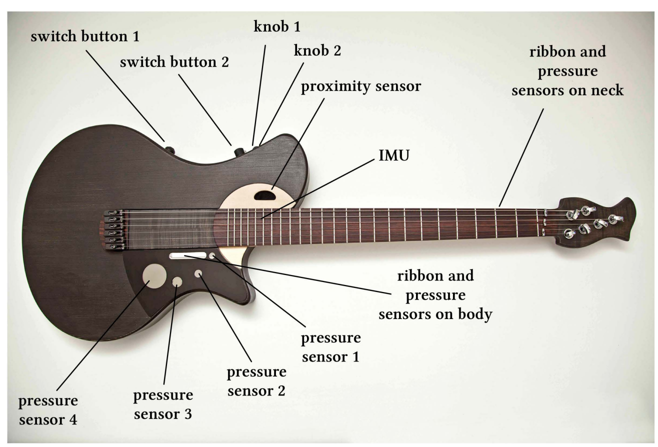

Figure 1. The Sensus guitar.

The Sensus Guitar

The Sensus Guitar (Figure 1) is an electro-acoustic guitar developed by the startup MIND Music Labs and designed according to the Stradivari tradition [54] and crafting techniques. It is enhanced with sensors, actuators, and an embedded computational unit which allow guitar players to generate and modulate sounds through various movements and bodily actions additional to the conventional playing technique. It is equipped with the regular knobs, switches and buttons of an electric guitar, as well as with various sensors and accelerometers embedded in different parts of the instrument. The sensors have been integrated into the guitar by using digital luthier techniques [30], adding digital augmentation to a traditional instrument.

The sensors allow for the tracking of a variety of gestures and movements performed by the guitar player, including pressure and position of finger on different areas of the instrument, the proximity distance between the player's hand and soundboard, as well as the position of the instrument and its linear acceleration along the three axes. These sensors are mapped to parameters of a sound engine running on an embedded system to generate synthesized sounds, and to record and playback features. The multiple actuators (e.g. the speaker) that are attached to the instrument, are designed to deliver the digitally processed, or generated sound without the need of external loudspeaker. A more detailed description of the technical properties of the instrument is provided in [52]. This includes details about the wireless connectivity, and the mapping of the actuators and sensors to the sound control. We invite the readers to turn to these references for more details about the implementation.

What is interesting to note here is, however, the fact that from a design perspective the guitar is regarded as a smart instrument on the base of specific technical qualities. Firstly, the integration into one single device of a range of equipment otherwise necessary with a traditional electric guitar — i.e. cables, soundcards, laptops, analogue or digital effects provided through pedals, synthesizers, drum, machines, samplers and corresponding controllers. Secondly, and relatedly, the generation and control of sounds through the embedded sensors and sound engine characterize smart as enhanced computation and as an active property enabling guitar players to explore novel ways of expression [52].

METHOD

The goal of the study was to investigate professional musicians' first reactions and reasoning about the smart qualities of Sensus. The study was carried out in the context of MIND Music Lab's ongoing development of the the smart guitar, and they were responsible for recruiting the participants for the study.

The sampling of the study was purposive and being a professional guitar player was the main criteria for inviting participants. For the scope of this work, we regarded as professional those musicians who are used to performing live and to receiving monetary compensation for this type of work.

The study was designed as a technology trial[11] and carried out in the context of a broader design process whereby the smart guitar was iteratively prototyped and redesigned by MIND Music Labs. Eleven participants were recruited, all were male ranging in age from 29 to 58 (average 34) with different music genres covering classical, country, folk, punk, jazz and rock. They all played a variety of instruments, but the guitar, acoustic or electric, was their main musical instrument and, in average they had been playing it for about 20 years.

Data Collection

The trial was carried out over four days, with about an hour allocated to each participant. In the beginning of each session participants were asked if they were already familiar with the concept, and the main features of the Sensus guitar. All the participants reported having seen the promotional video — released on YouTube two months before — although they had not been instructed to watch it. It is, however, plausible that their expectations about the technical features and the smart qualities of the instrument were partly shaped by the video. No instructions on how to use the guitar were given before handing the instrument, and none of the participants had previously used the guitar.

Participants started by using the guitar for fifteen minutes (Figure 2). They were told to try the guitar as they liked, either by trying to play a tune, or by exploring its technical features. Immediately after, there was a discussion of their initial experience, focusing on the features that they had been able to test, and those that still remained unclear or unexplored. These sessions were video recorded and observed by the second and fourth authors. Just over eleven hours of video material was recorded in total.

After this session, the second author conducted a semi-structured interview with each participant in a separate room. Interviews lasted between 25 and 35 minutes, they were all audio-recorded and transcribed immediately after. The goal of the interview was to gain an understanding on the musicians' first impression of the guitar, the experience of playing it, and what they had managed to do — or not to do — with it, and how they experienced its use in relation to their music practices. While an amateur may be unable to extrapolate within this time frame, we believe an expert guitar player — who is highly versed in different configurations of strings, recording equipment, pedals, and widgets — is well placed to create realistic narratives around its potential use and shed light on the possible appropriation of the instrument.

DATA ANALYSIS

The data were analysed recursively in joint sessions following the principles of thematic analysis [12]. The initial themes emerging in the analysis were derived from the participants' interviews and the video material. During a first round of analysis we identified overarching themes related to the musicians' appropriation of the smart guitar, the reliability of the instrument, the expected process of learning to play it, the expected impact on performing live with it, etc. During a final round of analysis, we chose the themes that enabled us to unpack the musicians' sense-making of the smart qualities inherent in the guitar, and how this may impact on the future use they envisage. These themes are representative of all the interviews, and they capture elements of the participants' orientations towards interactive technologies in the context of their performance practices. Investigating this felt-like experience [35] — as an alternative to more functional issues (e.g. usability and affordances) — is central to settings where both functional aspects of the technology and bodily, sensorial and emotional aspects become critical to its use [1, 58].

Figure 2. The Sensus Guitar in Action

RESULTS

In what follows we introduce three themes illustrating the musicians' sense-making of the smart qualities of the guitar. The themes illustrate the narratives [25, 35] the participants started to developed about the smart functions of the instrument, and how they could be put into use while performing. The sections below bring attention to the participants' narratives about smartness in relation to *i)* the agency of the guitar and the music skills involved in playing it, *ii)* the transformation of actions entailed in artistic practices, *iii)* the musicians' reflections and imaginations of how the guitar could expand their performances.

Agency and Skills

The first theme connects the musicians' perception of the smartness of the guitar to the sense of agency [51, 55] that was ascribed to it.

Throughout the interviews, the participants repeatedly discussed the experience that the guitar was "doing things", such as generating sound effects (i.e. the wah-wah or the echo effect) traditionally associated with the use of external pedals, amplifiers, or dedicated software. A guitar pedal (also called stompbox) is an analogue or digital device that guitarists activate with their feet to modulate the sound of their instrument to apply an effect, such as a delay or a reverb. Typically guitarists use a variety of pedals interconnected between each other and mounted on a pedal board. In Sensus, the integration of a variety of functionalities and sound effects in a single object reflected on the narration associating smartness with having a brain and, thus, being able to act:

> It's like just more of everything in the same instrument . . . it's like there's more than a guitar, it's not only like an instrument, it has its own brain, it does a lot of stuff . . . it's more I don't know what, a smart guitar, a tool. [. . .] It feels weird just refer to it as an instrument because it's more — D

The novelty of the guitar was a source of enthusiasm for many participants, particularly with respect to the integration of digital and interactive components into a traditional instrument. However, the attribution of smart qualities associated with this design highlighted two main challenges the musicians experienced in relation to the skills involved in mastering, playing and performing with it.

During the interviews, the participants extensively discussed that the ability of the guitar "to do stuff" on its own transformed their skills and expertise from musical to technological. Reconfiguring what the guitar can do was a common topic during the interviews. For instance, participants discussed the possibility to deactivate certain effects (the wah-wah and the tremolo, for instance), or to change the interactions needed to activate them (i.e. the accelerometer and the movements associated with it). This was however experienced as challenging. Reconfiguring surfaced, in fact, a tension between the participants' understanding of the expertise entailed in playing the guitar, and of the technical skills they thought would be necessary to hack, or recode some of its functionalities:

> I think that guitarists they are not computer geeks, or maybe I'm wrong. Maybe the new generation are more into that, but still for me I think if you work with keyboards you are more into new technology and if you're working with a guitar you just want it to work — H

Furthermore, the quality of the guitar to digitally generate and control sounds without external equipment was perceived by the musicians as occurring beyond their control. One participant discussed this in terms of lack of explicit feedback, particularly in relation to the pressure sensors #1, 2, 3, 4 described in Table 1:

> I think to me what I miss sometimes is the feedback. The tactile feedback. — F

The feedback mentioned in this quote is the way a guitar "talks back" to a musician when it is being played. As it was explained, musicians learn to feel with their body how actions result in a variety of tactile and auditory effects in the instrument — for instance, how specific ways of striking the strings results in certain vibrations. With the smart guitar, however, the musicians were not able to associate sounds to vibrations, which interrupted their ordinary experience of playing. Thus, while with a traditional guitar the experience of playing and sensing are phenomenologically collapsed, perceiving that the guitar could do things on its own transformed this experience into two discrete and separated moments. This resulted in a sensorial gap and the feeling that more feedback was needed to understand what was happening. Certainly, this way of feeling can be developed through practice. What is relevant to note here is that the initial-ness of the sensorial engagement with the guitar is connected to being able to control and understand what the instrument is doing.

Figure 3. Exploring the Front-Back Movement

Transformation of Action

The second theme addresses how the musicians experienced the agency of the smart guitar as transforming the meaning of the actions whereby it was played. Since the sensors were oft-times perceived as acting beyond the musicians' control, their smart qualities were associated with the degree of autonomy they displayed. In this regard, the analysis below highlights how some bodily movements and actions were re-choreographed in the musicians' attempts to put the sensors into use and to understand how they worked. For instance, Figure 3 shows a participant exploring a front-back movement. This is enacted by extending the arm holding the neck of the guitar and slightly rotating it forward. As described in the table 1, this movement is mapped to the triggering of a note of a synthesizer.

This point resonates with Taylor's [48] reflections on how interactions with objects displaying intelligence need to be seen as 'engineered', and how the experience of intelligence emerges through the on-going reconfigurations of human-machine relationships. The initial relationships that the musicians developed with the guitar, were therefore attempts to master and appropriate the digital components into their consolidated playing practices.

As it emerges from our interviews, several of the participants emphasized — perhaps not surprisingly - that playing a guitar is an experience involving a broad range of bodily actions. The participants repeatedly discussed how a guitar is not merely played with one's own hands and fingers, but also with one's mind, heart and the whole body. Some actions, such as using hands and fingers to pull the strings, are made to play the instrument and to produce the actual notes and melodies of a song (explicit movements). Other actions were instead more connected to the broader experience of performing (implicit movements), such as keeping the rhythm of a tune, following the moves of other musicians, or merely engaging with the music played. In the case of this smart guitar, however, some movements were actually sensed by the guitar, thus becoming explicit ways of producing sounds and effects that were unintentional or unexpected. As formulated by two of the participants:

> I accidentally pressed that thing on the neck so it made a sound when I didn't expect — C

> I was much more aware of how to move it just because this movement makes an effect or this movement makes an effect, which are movements that I wouldn't normally think about. I would do this if I feel like it, but not as a conscious act to change the sound. Now it's like, it's an actual conscious thing to move the guitar like this. Yeah, I think I play it differently. — F

The various ways of engaging with the whole body was thus central to the interactions between the musicians and the guitar. This experience, however, "broke down" (in the Heideggerian sense [16]) when the smart guitar produced sounds and effects unexpected from their intentions. Such aspects of interactions with digital artefacts are extensively explored in interaction design (e.g. see [2, 7]). What is relevant here is that the embodied actions performed to play the guitar become a means to explore and understand its smart features. This connects the exploration of the technological layer enabling it, and of what movements become meaningful interactions with the instrument.

Expanding the Performance

The last theme discusses the smart qualities in relation to the musicians' imagination of how the guitar could expand their self-expression and stage performances. This means, for instance, that the guitar was not merely discussed as an instrument to produce sounds and music. The narrative developed on how to put it into use also entailed tropes regarding the possibility to expand how music can be "expressed" rather than simply played. Musicians move on the stage for many reasons, such as to entertain the audience or to express their emotions [15]. This point was particularly discussed in comparison to other instruments for which body movements are inherent the modulation of sounds:

> This feels like an interesting idea about moving the guitar around and get that sound, because then you can adapt your performance to that [. . .] You can do just a small change and you get in to it. It's like performing with violin you need to get the flow into the music. — H

Another issue emphasised during the interviews was the musicians' conceptualization of the guitar as a 'multi-instrument' that allows to produce sounds of different instruments (e.g. a drum). Interestingly, this feature was not described in relation to a "solo" performance, in which a musician plays a piece with only one instrument. Our participants saw, instead, this feature as a transformation from playing in a band (with other people) to being a "one-man band". This means that one musician is enabled to play several instruments and to perform in different roles, (e.g. by producing different sounds and effects, or controlling a backing track):

> I can perform with this [Sensus] in a different way. I can be a one-man band for instance. You don't need to have all these instruments, all these effects, all these things around. If I want to play the drums . . . everything is here. I can make fairly advanced compositions with just this instrument. — F

The participants also discussed their roles and responsibilities within a band. While referring to the different features associated with a multi-instrument, they saw themselves both as sound producers and guitar players. This was envisioned, for instance, as an opportunity to accompany the band on stage even when a guitar is not included in the original composition:

> It'll make guitar players be able to be more part of a production sound in a band context. — N

DISCUSSION

The strive for technological innovation and the design of smart technologies poses interesting challenges for HCI. As we have seen in the analysis, within professional artistic settings the integration of digital components into a long-established instrument can create tension with consolidated music expertise and skills, with the musicians' expectations about the role of the instrument, and with the musicians' role during music performances.

The notion of co-performance has been suggested [33] to indicate that smart, computational artefacts can learn and perform social practices through sustained interactions with humans. Distancing from a notion of smart as autonomous, this work shifts the focus of design from issues of distributing agency between humans and autonomous smart objects, towards enabling both humans and artefacts to learn together desirable social practices and roles. Resonating with the practice-centred orientation towards smart technologies, this paper raises questions regarding how HCI can make sense of people's (re)conceptualizations of mundane artefacts that are combined and enhanced with smart technologies, and how this discourse can inform related design aspects. In the following sections, we present three overarching issues that help us better understand smartness in the context of everyday and future professional practices.

Firstly, we address how the perceived smartness of the guitar intertwines with issues of human creativity and the sense of agency and partial autonomy the musicians' attributed to the instrument. Secondly, we draw attention to the conceptual challenges that emerge from interweaving analogue and digital materials. Finally, we discuss longevity and its relations to designing smart objects entailing digital and analogue components. These issues point to three sensitivities that, we argue, should be foregrounded in designing smart objects, namely: *i)* new skills and expertise might have to be acquired, *ii)* this should be regarded as something to strive for (and not as a design error), *iii)* users should be enabled to customise and replace the embedded digital components, and to re-map their associated functionalities.

Understanding smartness in professional practices

Our analysis has focused on how the musicians perceived that the smart guitar constrained, but could also expand their skills, expertise and modes of expression. The issue at stake here is not to predict the future success or failure of this type of instruments [32]. It is rather to illustrate how smart qualities, characterised from a functional perspective and conceived at a technological level, are then understood in the context of situated practices and expertise. Thus, the design and implementation focus on aspects such as integration, enhanced computation and active properties triggered an extensive discussion on the musicians' perceptions of their body movements during a performance, new responsibilities and opportunities in a band, and on aspects of agency and autonomy attributed to the smart instrument.

Smart technologies (e.g. the Amazon WeMo) are often supported and promoted by their promotional videos and the aspirational ideal that they sell, and it is in these aspirations that the desire for these devices is born. In the case of smart instruments the skills associated to the base instrument (the analogue one) and the skills associated with the smart features are bound together creating a challenge for the design and dissemination of this ideal.

Envisioning Expert Use

One way the musicians characterised the smartness of the instrument was through the sense of agency they attributed to it. This was described in relation to its all-in-one design, and the fact that effects (e.g. the wah-wah effect), traditionally associated with external gadgets like pedals, could be triggered by interacting with a proximity sensor located above the strings of the guitar (Figure 1). The agency associated with the smartness of the guitar was therefore articulated as a tension between "what the instrument does" and what "one can do with it". As seen, these two dimensions collided with each other as the musicians encounter the smart guitar for the first time. Arguably, the process of mastering the musical instrument [56] can be seen as reducing the agency associated with its smart computational qualities. This is, however, a complex relationship that evolves over time and whose understanding should stem from longitudinal, empirical studies. Here, we emphasize that the very idea of mastering the instrument and learning to play it reflects on the musicians' attitude towards it and their inclination towards wanting to using it (or not). We come back to this point in the following section.

The smartness of the guitar was also referred to its partial autonomy, with certain movements triggering unwanted or unexpected effects. This had important consequences, as the ways musicians interact with instruments is functional to playing the music (explicit movements), and to generate expressive ideas about music (implicit movements) [15].

The musicians also felt that they needed to reconfigure their skills and expertise in order to be able to play Sensus. For instance, this was associated with the idea that being a guitar player does not necessarily mean being a technology savvy and that an understanding of how the digital components work would be necessary to appropriate the guitar and personalize the technological layer (i.e. different mapping between sensors and sound effects).

Envisioning the Acquisition of Skills

The functions of tools are not attributes but, as Ingold suggests [25], narratives about their use. To recognize an object as a certain tool, and to use it appropriately, it is important to understand its narrative of use, or to be able to develop a new one about it. Thus, "bringing into use is not a matter of attaching an object with certain attributes to a body [...] it is rather a matter of joining a story to the appropriate gestures" [25, p.73]. As the analysis shows, bringing into use the smart guitar has strong relations to how the participants perceived it would reconfigure the performative aspects of the interactions with it[15, 27] — particularly the spontaneous movements activating sound effects, or other body movements that would have to be re-choreographed to play certain effects.

The initial friction between the new affordances and the learned practice of the player can be seen in the light of their hard-won expertise with the instrument. An experienced player has the knowledge and experience to, on some level, make a judgement on the time and effort that would be necessary to change their practices, and learn to integrate skills with these new affordances into their current repertoire. This allows them to effectively cost their narratives of expert use against narratives of exploration and practice. In areas where our participants could see a direct path towards skill, or a higher value in the envisaged expert usage, they were more positive in their discussion of the smart qualities of the guitar.

This suggests that introducing technological innovation into practices as highly skilled as the ones we studied, designers could paint them in the light of the common skills that would have been acquired by their target audience. Another option would be to explicitly state the average length of time that the learning, or re-learning, necessary to master a new feature took a sample of experienced players. This may seem counter-intuitive alongside 'plug-n-play' consumer smart devices, where stating that tens hours of practice would be necessary to master it would be taken to mean that the interaction is flawed in some way. However, the respect for practice and dedication in artistic and creative practices like musicianship should be embraced rather than ignored, or avoided. Our previous work [1] shows, for instance, that the introduction of interactive technologies into theatrical settings was for the artistic team a playful, although demanding challenge, and that dealing with the associated problems was an opportunity for creativity and skill development.

Interweaving Smartness with the Analogue and the Digital

Our second point regards the conceptual challenges emerging when analogue objects are augmented with digital technology. In our case, this includes not only additional possibilities for playing and performing music, but also transformations of the skills required to effectively use the instruments, and the experience of using them. More fundamentally, this relates to the discourse on how interaction design needs to rethink the distinction between the analogue and the digital and, consequently, its impact on the way we conceptualize smart, interactive artefacts. One central tenet is, for instance, to recognize that smartness emerges from practices, traditions and expectations of use associated both with the digital and the analogue. This tightly connects to Fernaeus et al's [18] argument in their analysis of the Jaqcuard loom that "computation [or smartness] can never be understood through a distinction between the digital and physical", but rather emerges in the meaning-making practices in which these elements are intertwined and rely upon. To design for smartness, is then a matter of finding ways of gracefully blending interactive properties not only with the physical object as such, but in the larger scope of interacting and performing with it.

Similarly, the intersections between the digital and the analogue opens up new ways of seeing and enacting intelligence (i.e. [48]). This is a twofold question about what we regard as smart qualities of an object, and what we consider as the salient qualities that make us recognize an object for what it is. This, we argue, is a common challenge when designing smart technologies. For instance, while Sensus was regarded as a guitar by most of our participants (i.e. it required the skills of a guitar player), its digital computation expanded their imagination of what constitutes a guitar: "it is a guitar, but not as we know it", as one of the participants put it. While smart objects retain certain functions traditionally associated with the analogue object they relate to (i.e. people might put mugs on a smart table), they also display new ones. It becomes therefore relevant for HCI research to consider: *a)* how analogue and digital components transform each other, *b)* how interweaving the digital with the analogue reflects on the qualities of smartness that people associate with their professional practices.

The layering of IoT with the Carolan guitar [4, 5], for instance, expands the role of the instrument beyond the traditional narrative generally associated with such an instrument. It enables to perform music, but also to collect the stories and events that unfold around it; this transforms consolidated orientations towards instruments: people can be their custodians rather than simply their owners. Similarly, the intersection of the analogue and digital in Sensus reconfigured the musicians' narratives of what it would entail to play it, including the possibility to customize it, and to (re)assign different body movements to the sounds they would trigger.

Rather than smartness being layered on a guitar, which would leave the fundamental nature of the instrument largely unaffected, in Sensus the computational transforms the core nature of the instrument. It supports, enhances, and extents the playing of the guitar rather than other activities around it. As discussed above, the new features were at times felt to be intruding on the skill and nature of guitar playing—this can be seen as a consequence of the interweaving, rather than layering, of digital technology. So where in a layered device we may discuss such interference with long-standing skills and practice as an error in design, in an interwoven device the modification of skills and practices should be expected, and designed for.

Designing for Smart Longevity

In concluding this paper, we draw attention to the notion of designing for longevity. This is to be interpreted as a sensitising theme to think about the experience and design of smart objects, rather than a suggestion for a concrete implementation or design. Longevity here is related to the musicians' experience of using the instrument, rather than to the practices and processes of instrument design. As such, it is different from other discussions on longevity [38].

Designing augmented and smart instruments entails a number of challenges that bring together a variety of theories, methods and expertise at the intersection of HCI, Computer Science, Psychology, Musicology and digital luthier techniques [23, 30, 41]. This includes, for instance, being aware of the physical characteristics of wood and sensors and to explore how they fit and work together. However, as argued in this paper, it also entails a careful consideration of : *i)* how people make sense of smartness as a living quality shaped in — and by — the context of their practices, *ii)* how smartness emerge from interweaving the digital and analogue components, rather than from merely the digital.

One issue extensively discussed during the interviews was the longevity of "traditional" instruments. Most of the participants owned several guitars which, as noted, are seldom replaced as a new model is released. Professional guitar players — acoustic or electric — select their instruments based on different qualities and personal interests. These qualities can include the type of wood used, its colour and look (e.g. retro or modern), the luthier who has designed it, previous owners, as well as genre specific aspects such as number of strings or tone. Moreover, these expensive instruments become even more valuable as they age. At the same time, however, musicians change and upgrade the gear and equipment usually used together with a guitar (e.g. pedals, pickups, or pegs). Thus, the separation between the instrument that is 'played' and the equipment that modulates the played notes allows the musician to replace the external equipment and add new abilities while keeping the base instrument.

While providing opportunities for innovation, smart instruments challenge this practice as they create a tension between the longevity of the instrument and obsolescence of the digital technologies embedded. The all-in one-design of smart artefacts, like the one we studied, risks interfering with the treasured preciousness of the instrument. This is particularly challenging if people cannot align these artefacts with their needs, practices, and with the fast pace at which digital technologies evolve over time. A straightforward way of addressing such design challenges would be, for instance, to give musicians the possibility to customise and re-map sound effects to the sensors of their choice, or to select which ones to (dis)activate. Moving from hardware to software, decreasing the amount of physical devices usually used can be seen progress and one would expect that all future instruments would take advantage of this opportunity—meaning that this tension of longevity would be only a problem while the market was in transition.

Another approach of more general interest to HCI research would be to carefully think of ways to connect smart qualities to the idea of designing for openness. This could include elements of modular design allowing the replacement of limited parts of the artefact, thus making the digital upgradable. This would be an alternative way to frame design and to assemble smart artefacts without the need to become a technology savvy. While such an approach would reveal additional challenges for designers, it could work as starting point for a discussion on how to seamfully interweave the design of smart technologies within the context of ordinary instruments and musical performance. This, arguably, could contribute to the long-term attachment to musical instruments and to other valuable objects such as interactive furniture [9, 8, 40, 46], or smart home devices.

FINAL REMARKS

In this paper, we have presented the results of musicians' encounters with a smart electro-acoustic guitar. Using observations of a technology trial and subsequent interviews, we have analysed how the participants discussed the smart qualities of the guitar in relation to their artistic practices. Our data shows that all participants experienced a sense of agency associated with the guitar, and that this was challenging as they experienced that they had to reshape their skills and expertise in order to control the guitar as it responded to actions a traditional instrument would not. Relatedly, we have discussed the transformation of both explicit and implicit body movements aimed at controlling and playing the guitar. As the guitar produced unexpected sounds and effects, it resulted in a breakdown of the experience. This was also an opportunity to reflect on the expanded opportunities afforded by the smartness to expand their performance or to accompany their band in different roles. The tension between the effort necessary to master these smart qualities and the enhanced possibilities envisioned can be seen as the tension between narratives of expert use and narratives of exploration and practice.

In layering smart technologies on top of everyday device, there is less interference with long-standing practices around the artefact. Interweaving however, redefines the core qualities that make an artefact what it is. This provides more opportunities for innovation but can result, for example, in a "guitar" which is no longer a guitar. Finally, interweaving analogue and digital components creates a tension between the longevity of the artefact and obsolescence of the digital technologies embedded. This is particularly challenging as technologies evolve over time or quickly become outdated.

In this paper, we have foregrounded the differences between adding smart features to a mundane object (e.g. vacuum cleaner robots, interactive thermostats) and one which is the focus of a skilled practice. As the field of HCI increasingly turns its attention towards IoT devices, it is important that developers and designers are aware that smartness cannot be generalised, and that the respect for practice and dedication should be embraced rather than ignored.

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