Semantic strategies in ubiquitous music: Deploying the sound sphere ecology in transitional settings

Damián Keller *, Brendah Freitas, Willian Ramon Barbosa Bessa, Ivan Simurra, Flávio Miranda de Farias

Abstract

We report the results of a study involving twenty subjects doing musical activities in transitional settings, supported by an ecology of tools based on the metaphor for creative action Sound Sphere. The Sound Sphere Ecology (SFE) is a set of web-based tools, loosely organized around audio mixing and processing tasks. It employs verbal strategies for knowledge transfer to provide support for lay participants and specialists. To understand how the stakeholders influence and are influenced by this design strategy, we carried out a series of experiments involving assessments of the participants’ behaviours and of the sonic products during various creative musical tasks with SFE. The overall results were positive, indicating that the proposed metaphor provides effective support for casual interaction, highlighting the participants’ level of engagement. As a downside, the assessments pointed to ease of use as the lowest and least consistent item among the rated creative factors. We discuss the implications of these results and propose various design enhancements to enable the usage of a larger pool of resources. Considering the heterogeneous profiles of casual stakeholders, methodological refinements are also proposed to assess the knowledge gained by the participants during the exploratory activities, while augmenting their ability to share knowledge. This is one of the first studies on creativity-action metaphors for casual interaction.

1. Introduction

Ubimus initiatives have ploughed the way toward the integration of novices and musicians as equal creative partners. This field of application – described as lay-musician interaction (Ferreira et al., 2016; Keller and Lazzarini, 2017) – unveils a potential tension between support techniques that foster creative results by relying on a pool of specialized tacit knowledge acquired through long periods of training and the creative strategies grounded on resources readily available to the untrained participants – linked to the manifestations of everyday musical creativity (Keller and Lima, 2016). This tension can be addressed through four approaches. One method entails the reduction of the novices to mere conduits of actions defined by the professional partners. This approach is exemplified by the piece Dialtones (Levin et al., 2001). In this piece mobile phones distributed in the audience are “played” by the musicians through a custom-made controller. The audience just provides the technological resources. Another method entails a design targeted exclusively at novices, at the expense of excluding professional participants. This approach is featured in the pioneering work of (Blaine and Fels, 2003). “The main factor common to most of the interfaces discussed herein is that musical control is highly restricted, which makes it possible for novices to easily learn and participate in the experience” (Blaine and Fels, 2003). This research avenue has been successfully explored by Mileto et al. (2011) in their online system CODES. CODES features a variety of strategies to support collective decision-making, including an integrated chat tool. Participants work on musical prototypes (shared persistent representations of musical products) that are constructed through the use of four-second sound samples, provided by the system. This limited pool of materials is usually sufficient for first-time participants. A third approach involves an exclusive target on the musical performance, while adopting a design based on a large pool of tacit knowledge built upon co-located acoustic-instrumental practices. This is the view proposed by the telematic approaches (Oliveros et al., 2009),

* Corresponding author.

E-mail address: dkeller@crrma.stanford.edu (D. Keller).

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Table 1. Three potential approaches to lay-musician interaction.

| Label                      | Design strategies                                                                 | Targets                                      | Examples                                                                 |
|----------------------------|----------------------------------------------------------------------------------|---------------------------------------------|--------------------------------------------------------------------------|
| Acoustic-instrumental      | Artistic performance-oriented design, based on a large pool of tacit knowledge built through co-located acoustic-instrumental practices | Synchronous performance, professional participants | Telematic music (Oliveros et al., 2009); smart instruments (Turchet et al., 2018) |
| Novice-centric             | Restrictive policies of access and control of resources are applied to enable the participation of novices in the creative processes | First timers, untrained participants       | (Blaine and Fels, 2003); CODES (Miletto et al., 2011)                    |
| Everyday musical creativity| These designs target transitional, domestic, leisure-oriented, work-oriented and informal educational settings | Creative activities in everyday settings, casual participation | Time tagging (Keller and Lima, 2016)                                     |

tailored for the professional musicians (see Table 1). Finally, several ubicmus designs have targeted the manifestations of everyday musical creativity (little-c music) by developing both synchronous and asynchronous tools for musical interaction in transitional (Pinheiro da Silva et al., 2013), domestic (Ferreira et al., 2016), leisure-oriented (Keller et al., 2013) and informal educational settings (Lima et al., 2017).

The last three approaches are based on the active participation of all the stakeholders. But there are differences in the target public and settings. The acoustic-instrumental approach fosters design choices based on co-located acoustic instrumental musical making as an ideal form of interaction to be achieved by all partners. Hence, everyday settings or casual participation are usually not supported. Novice-centric designs strive to accommodate the needs of untrained subjects through non-technical and simplified interaction metaphors and through a reduction of the number of resources. This suits the aims of newcomers but may become limiting when musicians are included in the roster of users. Little-c approaches to musical interaction encompass an open set of resources but so far do not provide support for transitions between the needs of lay participants and the demands of trained subjects (Keller et al., 2014). We believe that these conflicting demands may be partially addressed by verbally driven support tools.

2. Knowledge transfer through semantic strategies

Verbal strategies for knowledge transfer have a long history in music making. Verbal descriptions form part of common-music notation practices and include indications of agogics such as the andamento signatures (ritardando, accelerando and similar markings), dynamics (piano, forte, crescendo, diminuendo, etc.) and articulations or playing techniques (legato, staccato, col legno, etc.). They are frequently applied in acoustic-instrumental writing. These musical parameters usually do not require quantitative precision and may be very hard to quantify.

Verbal knowledge transfer was expanded by the experimental musical composers of the 1950s and 1960s. Purely verbal scores were used to depict actions that were not strictly bounded in time (despite being linked to specific spaces and objects) through procedural verbal scores. They also yielded verbose depictions of sonic outcomes, akin to literary versions of sonic painting. These forms of musical documentation broke with a tradition centred on pitch representation and prompted a search for alternative formats that highlighted the visual and literary aesthetic potential of musical notation. But these initiatives did not address the gap between the procedural scores and the use of quantifiable musical parameters, such as pitch, event onsets or event durations. Furthermore, the pioneering projects of the fifties and sixties were limited either by the extent technology or by the composers’ lack of access to computational tools. For instance, some early experimental pieces – heavily influenced by Xenakis’s work – made use of computers to introduce randomness into the aesthetic decision-making process (cf. Cage (1969); Silva de Marco (1964)). The expertise and intensive labour demanded by the electroacoustic studio precluded an early fusion of compositionally based and open-ended forms of knowledge transfer. Hence, a large amount of electroacoustic music making either relied on improvisatory approaches, leaned toward the use of real-time analogue synthesizers (Oliveros, 1966; Subotnick, 1967) or employed asynchronous data generation based on transcriptions for acoustic-instrumental players (Hiller and Isaacson, 1959).

Notwithstanding the technological advances of the last twenty years, current strategies for musical knowledge transfer still suffer from a conceptual split that divides the technologies for instrumental composition – exemplified by the sequencers and score editors – from the technologies for sound processing and synthesis. After the invention of the computer, Digital Audio Workstations (DAWs) are among the tools that have most radically changed music production. Since the late 1980s, audio editing procedures that took several months of work in the analogue studio can be done at home in a matter of hours with potentially better quality. But DAWs have incorporated so many features and functionalities that have become stifled and awkward when employed as creativity-oriented platforms. Most DAWs have adopted a standard metaphor based on the analogue tape that enforces the implementation of graphical user interfaces demanding large screen real-estate and plenty of computational resources: two items that are scarce in mobile and embedded devices. Furthermore, this metaphor is not always compatible with the representation of musical data for usage by acoustic instrumentalists. While common-practice notation employs a metric and hierarchical organization based on periodicity, the analogue-tape metaphor adopts absolute time as a tabula rasa. To align these two time models entails the application of ad hoc procedures, such as inserting cues in the audio material or detecting onsets and regularities that can be used to determine “a beat”. These strategies force an acoustic-instrumental way of organizing time onto the sonic material, providing an illustrative example of a musical bias caused by early domain restriction (Lima et al., 2012, 2017).

How can early domain restriction be avoided? How can casual users and beginners have access to audio mixing and processing in settings that were not built for music production? One factor is related to the availability of the tools. Since the initial experiments in ubiquitous music (Keller et al., 2011b; Miletto et al., 2011), the browser has been adopted as a prototyping platform of ubiquimus resources (Lazzarini et al., 2014; Wyse and Subramanian, 2013). Despite its multiple drawbacks (Lazzarini et al., 2015), the emergence of the Web Audio Library has provided a common ground for ubiquimus developments targeting web-based usage. Other relevant initiatives include browser-based deployments of acoustic composers such as Csound (Lazzarini et al., 2012) and Pure Data (renamed Kiwi) (Paris et al., 2017) and the languages that support multi-platform rendering, such as Faust (Orlarey et al., 2004).

Another factor that impacts the creative performance of both trained and untrained subjects is the usability of the support metaphors. Ubimus research has fuelled the design of a new generation of musical technologies, simultaneously flexible and intuitive. Their flexibility has ensured fairly long life cycles (some approaches have been around for a decade

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2 Música para diez radios portátiles / Music for ten portable radios.

3 See also the comments on the design of Hyperscore.

4 https://www.w3.org/TR/webaudio/.

5 https://ide.csound.com/.
and are still in use). Their naturalness has reduced the learning period to just a few minutes, thus enabling casual usage.

A characteristic of this generation of tools is its potential inclusiveness, encompassing a variety of stakeholders. Ubimus systems have been successfully tested by children (8 years or older), by the elderly (though in some cases with some restrictions) and by cognitively challenged participants (with serious handicaps) (Pereira et al., 2018; Pinheiro da Silva et al., 2013; Keller, 2018). Despite not being targeted to professional musicians, the creativity support metaphors were also positively assessed by musically trained participants.

To enable the development of the field, so far ubimus design initiatives have concentrated efforts on furnishing audio synthesis and processing tools for advanced users (Lazzarini et al., 2014), designing methodological frameworks for ubimus interaction (Camporez et al., 2018; Pimenta et al., 2014) and applying this knowledge to a variety of contexts involving novices (Lima et al., 2017; Miletto et al., 2011) and casual participants (Keller, 2018; Keller and Lima, 2016; Pinheiro da Silva et al., 2013). Given the promising results obtained in creatively oriented tasks by subjects with no technical training and with very little acquaintance of the musical tool set, could ubimus metaphors for creative action help to bridge the gap between the colloquial descriptions featured in the procedural scores and the deterministic representations of common-practice music notation and score-based computer assisted composition? At first sight, simplistic mappings or lookup charts of number-based and word-based equivalents seem to be enough to tackle this issue. Nevertheless, a closer look at this approach unveils a problem. Take, for instance, the dynamic level piano. If this dynamic marking is applied to the strength of a horn playing with a one-hundred brass-players street-marching band, piano means one thing. If it describes the dynamics of a horn line belonging to a wind quintet performing in a small auditorium, then it means quite a different thing. On a similar vein, a piano dynamic obtained by means of a breath controller driving a physical model of a tube is different from a piano event produced by pressing a key on a MIDI keyboard that drives a sawtooth-based synthesis algorithm. In these scenarios, the pitch and spectrum may be almost equivalent. But the time and phase relationships among the components produce perceptibly different sonic outputs. Furthermore, interacting through key-pressing entails a detachment that may be foreign to a musician accustomed with devices based on breadth control.

So, how can we reduce the complexity of the parametric controls while avoiding a negative impact on the aesthetic results? One path involves what can be described as predictive parametrization. By incorporating the background information of the resources in use, the stakeholders may have access to an enhanced set of constraints that furnishes a firm, yet flexible, context for creative decision-making. On the same vein, predictive parametrization involves one or more strategies to ground the aesthetic decisions at hand: (a) the metadata of the resources, (b) an accumulated log of previous decisions of the user or of other agents on related cases (i.e., a jurisprudence), (c) added constrained informational noise to augment the creative potential (also known as Gelassenheit factors) (Ali et al., 2018). How each component weighs on the creative support and on the creative outcome is a target of ongoing research.

Continuing with our example of dynamic markings, let us process an event by applying a dynamic envelope with break-points corresponding to forte and piano. In a direct-mapping procedure a fixed value could be assigned – let us say on a MIDI-based scale of 0 to 127, 105 as forte and 49 as piano. Using this method, all piano instances become equal to 49 and all forte instances are given a value of 105. Similarly, every occurrence of the envelope forte-piano has 105 and 49 as the two values of the break-point function.

### Table 2. Break-point values of a dynamic envelope (on a scale of 0 to 127), comparing mapping and predictive parametrization.

| Semantic tokens | Mapping instances | Predictive-parametrization instances |
|-----------------|-------------------|-------------------------------------|
| forte           | 105, 105, ...     | (range 90 – 110): 92, 107, 99, ... |
| piano           | 49, 49, 49, ...   | (range 40 – 55): 47, 41, 54, ...   |

Contrastingly, a predictive-parametrization procedure may define forte as a range, let’s say from 90 to 110, and piano as a break-point value to be set within an interval ranging from 40 to 55, for instance. By applying constrained randomness, the first iteration of forte could be 92, the second 107, the third 99, etc. Also, the first instance of piano could be 47, the second 41 and the third 54. Examples of forte-piano break-point values are 101 and 55, or 91 and 50, or 108 and 40. Given perceptually defined ranges for each dynamic marking, both piano and forte become mutable but self-consistent entities that do not depend just on a single user decision but entail negotiations between the previous and current context and the actions of the stakeholders. (See Table 2.)

Furthermore, the temporal variability of the envelope is established by the actual timings of each break-point value. If this process is grounded on human actions based on auditory cues (i.e., press a button when you hear the material to be assigned forte and press a button when the piano dynamic begins), then the timings become dependent on the stakeholder’s understanding of the musical context that precedes each action. The ubimus literature defines this procedure as time tagging (Keller et al., 2010; Keller, 2018; Radanovitsch et al., 2011).

The description of the previous paragraphs is just a bare-bones example to illustrate a general design procedure. There are more complex examples in the literature (cf. Canazza et al. (2015)). We chose to focus on Gelassenheit factors for the control of dynamics, relying on a simple randomization mechanism with fixed ranges. The temporal outcome of each decision rests on the assessment of the local sonic cues, informed by the stakeholder’s aesthetic criteria. The refinement and the complexity of the aesthetic decisions are usually related to the requirements of the creative activity, to the local materials and to the stakeholders’ technical constraints.

### 3. Expanding the Sound Sphere Metaphor

To investigate the limits and possibilities of predictive parametrization, we are developing a new metaphor for creative action based on the Sound Sphere Ecology (SFS). This is an ongoing series of prototypes that add new functionalities and changes to previously published versions of the software (Bessa et al., 2015; Pereira et al., 2018). We deal with the mechanical aspects of multimodal interaction, encompassing touching and speaking (stage 1, controller). We discuss the selection of audio-processing strategies that are amenable to this treatment and point to some cases that may not be well supported by this approach (stage 2, modelling). And we search for parameters and parametric ranges that are good candidates for sonic renditions, providing examples of potential targets (stage 3, viewing – in this case more accurately described as rendering). The conceptual implications of stages 2 and 3 are also approached through a discussion of the extant literature in an attempt to address other problems unveiled by the prototyping process.

#### 3.1. Touching and Speaking

Time-based parametric manipulation presents at least two difficulties for activities involving untrained subjects. One issue is related to the choice of the parameter ranges. Some parameters demand a very fine resolution. Take, for instance, tuning. Human hearing is sensitive to small pitch variations, much finer than the frequently adopted interval of a semitone. Depending on the creative musical approach, pitch choices may be established through fairly coarse categories (e.g., a high-register pitch or any pitch in the low register) or may involve very small steps, from 10 to 25 hundredths of a semitone. The interaction mechanism employed to visualize and handle pitch may not correspond to
the quantization or the scale applied by the sonic-rendering model. An illustrative example is provided by HyperScore (Farbod et al., 2004). Its graphical interface lets the users "paint" the musical parameters. Upward lines correspond to ascending pitch sequences and downward lines indicate descending pitch sequences. Nevertheless, this continuous representation is misleading. When sonified, pitch gets quantized into temperament-based steps. Furthermore, visual blocks are rendered as tonal chords. This begs the question: Should the sonic rendition and the visual display be closely related? Or are vision and hearing completely independent modalities that afford arbitrary mappings?

Some metaphors for creative action strive to achieve a tight consistency between the chosen set of musical entities and the proposed interaction mechanisms (Keller et al., 2010; Elblaus et al., 2012). This is not a mapping issue. As shown by the rapid developments of computational-creativity approaches in music making, meaningful musical entities may encompass either creative products or processes that impact both the stakeholders’ behaviours and the sonic outcomes. According to a recent definition of ubiquitous music (Keller and Lazzarini, 2017), ubimus activities shape and are shaped by behavioural ecologies. Thus, interaction design for ubimus does not only entail the relationships between the visual and the sonic entities, it also includes the stakeholders’ behaviours, their impact on the local environment and the ensuing limitations and opportunities for new creative endeavours. This broader approach to design fosters a direct engagement with the extant behavioural resources.

As already discussed, verbal interaction – together with the exchanges based on mimetic gestures – is a knowledge-transfer strategy shared by both lay stakeholders and specialists. There is a rich musical vocabulary created around the sonic qualities of instrumental practices (Traube, 2015). Could these specialized tokens be adapted for casual usage? This is an open question for research. Semantic creative anchoring (ASC) is a metaphor for creative action that involves the use of words as tools to foster creativity in musical performance and in compositional activities (Keller and Feichas, 2017). As an expansion of ASC, we propose the incorporation of quantitative parameters through semantics-based approaches. Two existing proposals provide indications that the use of semantics may reduce the technical barriers of tool usage: Audealize and SAFE.

Audealize (Cartwright and Pardo, 2013; Seetharaman and Pardo, 2016) features two systems: one for the configuration of equalization parameters and another for the control of reverberation parameters. The target of this proposal is the implementation of equalization and reverberation tools handled through perceptually relevant descriptors rather than through the manipulation of the underlying acoustic variables (such as reverberation time, absorption and other low-level parameters). The Audealize interface displays user-created descriptors of parametric settings. Its display applies the metaphor of the tag cloud. Parametric configurations can be changed by clicking on each tag or alternatively by manipulating the control sliders corresponding to the gain at each frequency band of the graphic equalizer, or by setting the knobs to control the reverb parameters (in this implementation: reverb time, echo density, clarity, central time and spectral centroid).

Rather than developing a web-based system, Stables et al. (2014) chose to enhance the functionality of desktop based digital audio workstations through semantic control. The SAFE plug-ins (short for Semantic Audio Feature Extraction (Stables et al., 2014)) provide both parametric management and visualization tools with a semantic representation for a particular feature or grouping of features. SAFE makes use of semantic tags to control the parameters of functionalities such as equalization, distortion, compression and reverberation. It also enables parametric changes by means of graphical displays. Accordingly, the stakeholders are able to either store or retrieve previous feature settings by choosing a single tag. Moreover, the SAFE tool allows the users to insert personal and audio-oriented metadata (e.g., subject age, place, musical production background, musical genre or instrumentation).

4. Knowledge-transfer strategies in SoundSphere

The Sound Sphere Ecology (SFS) is a set of web-based tools, loosely organized around audio mixing and processing tasks. The SoundSphere 1.4.1 prototype features a selection panel and a mixing panel. Stereo, PCM audio files are imported at the start of the session and are displayed in alphanumerical order, each item featuring a distinctive colour. After clicking on the icon, the user can insert several instances of the selected audio simply by touching (clicking on) the mixing panel. Each action creates an event, its width being proportional to its duration. For prototype-testing purposes tracks are limited to 80, and the total duration of the mix cannot exceed an hour.

Since version 1.4.1 of the SoundSphere prototype,8 we have been experimenting with semantics-based designs. After various iterations, we settled on a mechanism to support complex parametric configurations of audio-processing tools (defined as semantics-timbre operators) through verbal commands. The tools include: 1. An interactive editor geared to advanced users that enables the configuration of filter banks, with any combination of the six filters featured in the Web Audio Library (low pass, high pass, band pass, all pass, notch or band reject and shelving) (see Fig. 1), 2. The support for a user-defined label to set and retrieve the filter-bank settings on the mixing panel, and 3. The retrieval of the presets by menu selections. These functionalities are provided by the SoundSphere and the Semantics-Timbre Operator Editor (TOE) prototypes 1.4.1 (see Fig. 2).

Our initial experiments adopted the labels and parameters proposed by the users of the Audealize tool (Cartwright and Pardo, 2013). According to the results reported in the literature, the use of a large number of labels, despite being supported through an ecology of tools, does not seem to furnish reliable assessments. After much discussion, we settled on a simple strategy to deploy the visual information. Eight preset descriptors – with unique labels suggested by the Audealize users – were chosen as the default settings for the timbre operators: small / large, light / heavy, dark / bright and cold / hot.9 This approach provides a balance between the flexible mappings – supported by the TOE-based, user-driven configurations – and the intuitive usage furnished by the semantic labels based on Audealize.

An issue we had to address was the labels’ legibility in less than ideal contexts of use. Among the factors that impact readability, we considered font size and the contrast between the letter and the background colours. The size of the letters depends both on the size of the screen and the browser settings. We leave these up to the user, since these configurations are supported by many operating systems and browsers.10 Legibility also depends on the duration of the event being processed. Most users employ audio files lasting at least a few hundred milliseconds. When combining long labels with short event durations, the size of the token tends to exceed the size of the event. To circumvent this

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8 Describer: timbre operator. Amplitude: magnitude of the chosen parameter to be displayed, this implementation displays the amplitude through various shades of grey. The SFS interface was implemented in Portuguese but it is available for usage in other languages through the Chrome translation tool.

9 To enable the participation of Brazilian subjects, the original Audealize labels were translated from English to Portuguese.

10 The development of SoundSphere has targeted Chrome (up to version 75) as its main deployment platform. But the design has been kept broad to enable support for other browsers. Current efforts include addressing compatibility issues with mobile platforms.
problem, we developed a simple procedure based on airport-name abbreviations (see Table 3). It selects the first character of the name (vowel or consonant), skips the remaining vowels and retrieves the second and the last consonants. The three-letter abbreviation is rendered in capital letters, making it compatible with both horizontal and vertical displays. Regarding the background colour, we avoid dealing with the event colour by using a double-edged font. The black outside-border ensures contrast with light event colours, while the white inside-border provides visibility when the background is dark.

Table 3. An abbreviation scheme was applied to enable displaying semantics-timbre operators attached to short events. The eight labels included in the table were deployed in the initial SoundSphere prototypes.

| Label in English | Abbreviation | Label in Portuguese | Abbreviation |
|------------------|--------------|---------------------|--------------|
| Heavy            | HVY          | Pesado              | PSD          |
| Light            | LGT          | Leve                | LV           |
| Bright           | BRT          | Brilhante           | BRT          |
| Dark             | DRK          | Escuro              | ESR          |
| Hot              | HT           | Quente              | QNT          |
| Cold             | CLD          | Frío                | FR           |
| Large            | LRG          | Grande              | GRD          |
| Small            | SML          | Pequeno             | PQN          |

The display of multiple types of information— including the semantics-timbre operators and quantitative parametric settings—indicated the need to handle alternative visualizations. Prototype 1.4.13 introduces the concept of layers into the Sound Sphere Metaphor. Each layer is attached to a sonically relevant variable. This mechanism features separate visual renderings for each audio tool. It also supports the composite display of multiple functionalities. To keep the design simple, while avoiding a disruption of the mixing-panel navigation and editing features, we decided to tie the input to each individual event and provide only a schematic visualization of the choices on the mixing panel.

Prototype 1.4.13 displays three layers of information: 1. audio content; 2. user-defined amplitude settings and 3. user-defined filtering (by means of the timbre operators). The audio content is represented by a colour that matches the display of the sound-sample icon on the selection panel. The amplitude level is defined in the event-editing window, from very soft in white (zero amplitude is equivalent to mute) to very loud in black. The timbre-operator configuration is displayed as a three-letter token placed at the beginning of the event.

5. Actions or sounds?

One difficulty of musical interaction design is to establish consistent bridges between the user actions, the parametric information being dis-
played and the sonic renditions. Natural interaction strategies usually entail isomorphic relationships between action, visualization and sonic outcome. But beyond the most simple cases, complexity rapidly builds up, precluding direct mappings (see also Dijadiningrat et al. (2007)). Take, for instance, the amplitude of the mix. This output depends on the level of each source, the dynamic envelope, the type and amount of processing and the number of overlapping events. Visualizing all these variables is feasible. But let us consider mixing 50 active tracks with displays and controllers for the source levels, the envelope levels and up to ten parametric changes per event. This would add up to approximately 500 elements to be updated for each event throughout the mix. Well, some would say that professional consoles have more controllers than that... That is exactly the point, we are not targeting pro usages! We want newbies and passersby to be able to engage meaningfully in creative activities. But this engagement cannot come at the price of a drastic reduction of functionalities, making the tools useless for musicians. The design choices imply prioritizing some aspects and abstracting others.

The Sound Sphere Metaphor gives priority to the information based on the user actions. Consequently, the interface elements provide a picture of the current choices which the participants can use as hints for collective decision-making. These include the sonic content – identified by the colour of the event icons (user-driven or automatically assigned based on the sources’ alphanumeric order); the event’s onset timing and duration (corresponding to the event position on the mixing panel’s horizontal axis and its length, respectively); a parametric magnitude (identified by the layer’s label and represented by the gradient’s shade of grey); and a timbre-operator in use (indicated by an airport-style abbreviation of the user-assigned descriptors).

The need to furnish visual information on the status of each event was unveiled in a series of experiments involving lay subjects. A first hint emerged during the imitation tasks. This activity demands an accurate reproduction of a model mix. The subjects can use both the sonic and the visual information available on the mixing panel. Most subjects could not complete the task and their assessments indicated a high level of effort plus some frustration. We were forced back to the drawing table. Why was their performance so low while the assessments and the sonic results of the exploration and creation tasks were all very positive?

When the usage involved multiple iterations, the problem was the lack of consistency between the visual information and the sonic content. The initial SoundSphere prototypes featured a colour-coding scheme based on random assignments. Two sessions with the same pool of sonic resources would yield completely different combinations of colours. This was not an issue in the exploratory activities or in the tasks that targeted the creation of new mixes. But it became an issue when the subjects had to reproduce a preexisting example. Most subjects disregarded the sonic information and followed the visual layout. Given the new pairings between colours and sounds the results tended to be quite different from the mimicked originals, hence the poor performance.

Another hint at the difficulties caused by the lack of consistent visual information was provided by experiments involving musicians. During a series of workshops realized in Goiânia (2015), Rio Branco (2016) and Monte videoe (2017), we received multiple suggestions and feedback from experienced colleagues.11 The SoundSphere prototypes deployed in these sessions featured support for audio-processing through the use of timbral operators. But the user feedback was only sonic. No visual counterpart to the timbral processes was provided. This was not identified as a caveat by the novices since the number of sources and the sonic modifications that they were handling were fairly limited. But it was reported as a problem when the usage targeted a large pool of sonic resources involving various types of sonic processing. Relatively complex projects demanded remembering which events were processed and which operators were chosen, forcing the users to go back and forth between the mixing panel and the event-editing window.

6. A case study: deploying the Sound Sphere Metaphor in everyday settings

Interactions in ubiquitous comprise multiple processes of decision-making. These include what to interact with and what actions impact the sonic results. The verbal strategies featured on the Sound Sphere Metaphor may provide support for lay participants and specialists. To understand how the stakeholders influence and are influenced by this metaphor for creative action, we carried out a series of experiments involving the assessments of the participants’ behaviours and of the products yielded during the creative musical tasks. Data was collected through automatic logs and through questionnaires.

6.1. Sonic resources

The sonic stimuli ranged from 3 to 9 seconds. Audio samples featured three distinct sonic classes: short solo piano (excerpts taken from Beethoven and Schubert compositions), biophonic sounds (collected at the Zoobotanical Park of the Federal University of Acre) and digitally processed instrumental excerpts taken from an instrumental composition, Decadent (Freitas et al., 2018). We used Audacity (Mazzoni and Dannenberg, 2000) to edit the audio samples. A total of 15 audio stimuli were chosen encompassing three sonic classes (piano, biophonic and processed instrumental sounds).

6.2. Materials

We used a 1.3 GHz quad core portable computer with 4 Gb RAM, running Windows 10. The display was a 13-inch monitor and the GUI was activated with an optic mouse. The SoundSphere application was accessed using a Google Chrome web browser, version 75. Throughout the creative session on the experiment, data was gathered through multiple queries targeting the sonic results and the subject’s performance ratings.

6.3. Creativity assessment

The Creative Support Index protocol was employed for data collection – CSI-NAP (Keller et al., 2011b). The CSI-NAP protocol12 assesses the impact of the tools, resources and activities through queries on seven creative factors: product relevance, product originality, ease of use, attention during the activity, enjoyment, productivity and support for collaboration. Answers are collected immediately after each activity. During the experiment, the volunteers are acquainted with the factors and the Likert scale. They fill a survey with values from -2 to 2 (Table 4).13 Besides the sonic results and subjects’ performances as aforementioned, the CSI-NAP protocol gathers information on the body positions, the duration of the activity and the features of the settings. The Brazilian National Health Council Resolution (510/2016)

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11 They are too many to list, but special thanks go to Luis Jure and Ernesto Donas (Universidade de la República, Montevideo), Marcello Messina (Federal University of Paraíba, João Pessoa), Anselmo Guerra (Federal University of Goiás, Goiânia) and Luzilei Alíel (University of São Paulo) for their suggestions.

12 The online form is issued in Portuguese (for the Brazilian participants) and includes the following questions: “Do you think that the result of activity was good?” “Do you think that the result was original?” “Do you think that the activity was easy?” “Do you think that the activity was fun?” “Do you think that the activity was productive?” Do you think that it was easy to collaborate?” For reference and comparison, please refer to the previous experiments that use a similar procedure with a comparable scale (Besin et al., 2015; Keller et al., 2011a, 2013a; Lima et al., 2012; Pinheiro da Silva et al., 2013; Pereira et al., 2018).
deals with the specificities of the humanities and social sciences. Research involving polls by unidentified volunteers or research that aims at spontaneous situations in professional practice, as long as they do not reveal the identity of the subjects, do not need to be registered by the council.\footnote{For more details, see: www.in.gov.br.}

6.4. Participants profile

A total of twenty students (7 women and 13 men) volunteered to participate in this study (ages: 22.75 ± 14.10). Participants reported an average of less than two years of musical training (training: 1.85 ± 2.70) and more than eight years of mobile-device usage (mobile-phone usage: 8.4 ± 2.43). Most subjects were undergraduate students.

6.5. Settings

The experiment was carried out at the central restaurant of the Federal University of Acre. The sessions were held after lunch. During this period of the day, these facilities are used for leisure and relaxing activities. Students usually lie on the couches, talking or using their portable devices. The acoustic properties of the space – despite its high ceiling – are not ideal for music purposes. The construction materials are highly reflective: All exterior walls are made of glass, the ceiling is raw concrete and the floor is tiled.

6.6. Procedures

The experiment encompassed four stages. Firstly, the participants got acquainted with the proposal and the current research initiatives of the Amazon Center for Music Research (NAP). The information on the objectives and motivation of the proposal highlighted aspects related to music making by novices and professional musicians. After the SoundSphere prototype was presented to the volunteers, the next three stages centred on the interaction with the tool. The activities were performed and rated with standardized criteria. Immediately after each activity, each participant filled the CSI-NAP form (see section Creativity Assessment for details).

Exploration. This activity targets the deployment of the SoundSphere resources with a given set of materials. Support for audio processing is also provided. The tasks include uploading, selecting and mixing the sound resources. The creative output is rendered as a stereo mix. There is no time limit to perform this activity. The timing of the user’s actions is automatically logged by SoundSphere.

Creation. The participants carry out a creative task using the sonic resources provided by the experimenters, including mixing and audio processing. The target of the activity is to obtain a creative product within one minute.

Imitation. The participants replicate a mix model furnished the experimenters. The sonic resources previously used in the mix are provided and the activity is constrained to a duration of one minute.

6.7. Results: creative factors

The scores provided by the twenty collaborators were analysed through descriptive statistics. The scores mean and the standard deviation were obtained from assessments based on a five-point Likert scale (−2 to 2). The highest ratings correspond to collaboration support and enjoyment (1.80 ± 0.40 and 1.70 ± 0.64, respectively). The subjects thought the sonic results were original (1.75 ± 0.66), but they did not reach the same consensus regarding the relevance (1.40 ± 0.66). Outcomes on attention and productivity were also positive but less consistent (1.50 ± 0.59 and 1.50 ± 0.67). The lowest score corresponds to ease of use – a factor that represents the inverse of the invested cognitive effort (1.15 ± 0.72).

6.8. Results: samples usage

Through an analysis of the session logs generated by SoundSphere, we obtained an overall picture of usage of the sonic resources (see the section Sonic Resources for information on these materials). Usage was similar for creation and imitation, with 4 to 5 samples loaded and deployed for each mix. An average of 7 events (instances of audio samples placed on the mixing panel) was employed during both tasks. Contrastingly, during the exploration tasks the subjects produced an average of 9 events. But this result was not uniform across all subjects (standard deviation = 4.32). In any case, a common tendency to use the samples repeatedly characterized the three activities. (See Table 6.)

6.9. Results: exploration timings

Exploration was the only activity that involved the assessment of temporal variability among the subjects. No participant was previously acquainted with the tool. This gave us a chance to assess the support for casual participation and to identify potential problems that could reduce the collaborators’ engagement during the tasks. Very short times would indicate lack of interest or inability to support basic functionalities. Very long durations could involve technical difficulties, distractions caused by environmental factors or an extremely high engagement in the activity. (See Fig. 4.)

The durations varied between 11:31 and 18:02 minutes. The average activity-length was 16:01. The standard deviation was only 1 minute and 26 seconds. Most of the subjects’ performances were evenly spread between 14:22 and 18:02 minutes. The subject that performed the activity much faster than the rest of the group (11:31 minutes) still took over ten minutes to conclude the exploration. Hence, we can rule out major technical or conceptual problems for this profile of casual participants.

7. Discussion

The results suggest a range of possibilities that point to advantages and limitations of the adopted design strategies. Firstly, the positive evaluations show that despite the complexity of the decision-making processes – which in some cases involve the selection and combination

Table 4. CSI-NAP v. 0.7: Likert scale and semantic descriptors associated for each value.

| Label             | Value |
|-------------------|-------|
| I fully disagree  | −2    |
| I partially disagree | −1    |
| I don’t know       | 0     |
| I partially agree  | 1     |
| I fully agree      | 2     |
of multiple sonic elements with a hard-to-predict impact on the timbri-
tic results – and the specific demands of casual interaction – targeting
music novices without any previous contact with the tool, all of the
participants engaged effectively in the creative activities. Their level
of engagement is attested by the scores given to enjoyment and by their
assessments of the relevance of the creative products. Granted, the lat-
ter aspect should also be put to test by employing other modalities of
evaluation involving multiple parties. More on this issue below.

The relatively low outcome of ease of use can be attributed to sev-
eral factors. Most of the collaborators did not have any formal musical
training and a minority had occasional experience with audiovisual
tools. Hence, it is not surprising that some of them thought the activ-
ity was difficult. When using the semantic-timbritic operators, both
the audio-processing method and the acoustic features of the source sam-

dles determine the sonic outcomes. In other words, the sonic results
depend both on the audio-processing parameters and on the charac-
teristics of the sonic resources. Despite this caveat, given the fact that
a novice participant – in an informal context and without any specific
training – can handle multiple audio contents and processing techniques
yielding a sonic result judged as satisfactory, confirms that the proposal
is feasible. Nevertheless, we also need to discuss what aspects of the
design could be refined without reducing the originality or the relevance
of the sonic products.

When comparing the timbre-interaction strategy employed in SFS
with the SAFE plug-in system and the Audelize web-based tool, several
differences in the integration of the functionalities and in the para-
metric mechanisms become apparent (see the section Expanding the
Sound Sphere Metaphor). Both Audelize and SAFE target isolated audio-
file processing. This functionality is equivalent to that provided by the
SoundSphere prototype on its audio-processing window. 15 Audio-
processing tools are rarely used in isolation. They are often employed
within the context of a wide range of creative activities (such as select-
ing sources, processing, editing and audio mixing), configuring what is
sometimes called the audio-production chain (Tatlas et al., 2003). Given
this context of use, factors such as the time invested in the activity and
the quantity or type of resources used are as important as the quality of
the creative outcomes.

A problem with the current SoundSphere implementation becomes
apparent in large mixing projects. When opening the window dedicated
to parametric modifications, four user actions are required per event:
open, apply processing, listen to results and cancel or save. By provid-
ing this functionality directly on the mixing panel, the iterative actions
may be reduced. A two-tier strategy – involving design and configura-
tion of audio processes as one stage and the deployment of processes
and mixing as a separate stage – may furnish a path to simplify this
 mechanism. Aside from the potential hardware constraints, in theory
there are no boundaries to adding audio samples or audio-processing
operators during a SoundSphere session. This potentially large number of
resources needs to be accessed directly. Thus, one or two extra oper-
ations per resource may have a huge negative impact on the quality of
the interaction. Another issue to be considered is the amount of timbre
operators as related to the quantity of audio samples employed in the
mix. Audio-trained musicians manage to make educated guesses on the
sonic outcomes of complex processing techniques. But this ability may
be reduced if multiple timbre operators are combined. Furthermore,
the action-oriented strategy of knowledge transfer applied in SoundSphere
may be less effective for combinations of multiple timbre operators.

The layering mechanism exemplified in Fig. 3 may provide a path to be
explored in future iterations of the design. Aspects to be considered in-
clude: the amount of timbre operators per event, the support for editing
without compromising other functionalities of the mixing panel such as
its navigability, the implementation of automation mechanisms to
enable detailed management of temporal features.

Ubimus research methods might help to gauge the impact on the
creativity factors of the adopted interaction support strategies. For in-
stance, strategies such as those applied by Audelize and SAFE could be
employed in conjunction with mixing tools (e.g., SoundSphere or
Audacity) to assess the temporal investment on the manipulation of
sonic resources, the ratio between resource usage and creative waste,
and the creative profile of the finished products. Long temporal in-
vestments or lack of originality of the creative products may indicate
cognitive demands unsuited for the stakeholders’ profiles. The analy-


15 The operator is displayed on the mixing panel as a two- or three-letter abbre-

viation (for example, hot = HT, bright = BRT). The user can choose a semantic
descriptor and hear the sonic results by hovering over the preview button.

16 This is a key contribution of this study. And it is a significant complement to
the musical interaction literature. There are very few studies that target casual
interaction.

Table 5. Creative factors assessed through CSI-NAP v. 0.7, displayed as means and standard deviations of the 20

| Subject’s scores. | Product relevance | Product originality | Ease of use | Attention | Enjoyment | Productivity | Collaboration support |
|-------------------|-------------------|---------------------|-------------|-----------|-----------|--------------|------------------------|
| 1.40 ± 0.66       | 1.75 ± 0.66       | 1.15 ± 0.72         | 1.50 ± 0.59 | 1.70 ± 0.64 | 1.50 ± 0.67 | 1.80 ± 0.40 |

Table 6. Mean and standard deviation of the number of sound samples used in each activity. The first column corresponds to

the quantity of sounds loaded, the second column indicates the sounds deployed and the third one comprises the total number of events

included in the mix.

| Activity       | Available samples | Samples deployed | Mix items |
|----------------|-------------------|------------------|-----------|
| Exploration    | 5 ± 2.28          | 5 ± 1.45         | 9 ± 4.32  |
| Creation       | 5 ± 2.54          | 4 ± 2.54         | 7 ± 2.58  |
| Imitation      | 4 ± 0.5           | 4 ± 0.89         | 7 ± 2.09  |
Zone of Proximal Development proposed by (Vygotski, 1978): Effective learning processes are characterized by challenging tasks that engage the extant knowledge of the participants. The tasks were not easy but the experiences were rewarding. Now we need to assess whether the knowledge gained from exploring the resources could eventually be transferred to other tasks or whether it could be shared among the stakeholders. This hypothesis demands identifying who does what in the context of iterative group activities.

Summing up, this paper unlocked alternative paths for ubimus research involving assorted participants on creative activities in an everyday context. The results are relevant to the extant semantics-based strategies for musical interaction and highlight new issues arising from the extreme demands of casual interaction. Knowing and handling small sets of resources is feasible within the limited amount of time typically available for activities in transitional scenarios. But are these strategies effective when the subjects are faced with large quantities of unknown resources? Furthermore, the proposed metaphor for creative action has yielded positive outcomes for individual usage in small-sized mixing and audio-processing projects. According to the results obtained in previous experiments (Keller et al., 2013), transitional settings tend to exert a positive impact on originality. However, the effect on relevance may not be uniform (see Table 5). In line with the results obtained in experiments with other metaphors for creative action (such as time tagging, spatial tagging, creative surrogates or graphic-procedimental tagging), the activities involving the SoundSphere prototypes fostered engagement and fun. Both the timings of the exploratory activities and the assessments of the creative processes and products indicate that subjects with no special training can handle complex musical processes and unfamiliar resources in settings that are not tailored for music making. Meanwhile, could these results scale up to group activities done by stakeholders with diverse levels of expertise? Are these results applicable to group endeavours carried out iteratively and asynchronously through network platforms? Future projects will focus on these aspects of timbre interaction involving groups of lay participants. Hopefully, the questions opened by this study may help to advance the agenda of a second wave of ubiquitous music research.

Declarations

Author contribution statement

D. Keller: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.
B. Freitas: Performed the experiments; Wrote the paper.
W.R. Barbosa Bessa, F. Miranda de Farias: Contributed reagents, materials, analysis tools or data.
I. Simurra: Analyzed and interpreted the data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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