A COMMUNAL MAP OF DESIGN IN AUDITORY DISPLAY

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ABSTRACT

The workshop on Recycling Auditory Displays at ICAD 2008 aimed to capture knowledge about the design of auditory displays from the participants in a manner that would be easy to understand and reuse. The participants introduced themselves by providing examples of a good and a bad sound design. These examples raised issues of culture, identity, aesthetics and context that are more usually associated with product sound design than auditory display. Based on these discussions the themes Users, Applications, Techniques, and Environments were chosen to focus the further development of ideas. A mindmapping session was used to collect over 150 entries under these themes, and more than 30 references. An additional Others theme was needed for ideas that did not fit neatly into the existing categories. The information that has been collected shows that most research in auditory display falls under the themes of Applications and Techniques. The information under the themes of Users and Others shows the overlap with related disciplines such as auditory neuroscience, product design, sound arts, semiotics, and interface design. The Environment theme raised the need for future research to include contextual issues. The outcome of the workshop has been to produce a collaborative understanding of the current state of design knowledge in the Auditory Display community, and to identify future directions for research into the design of Auditory Displays.

1. INTRODUCTION

The knowledge of how to build a `good' auditory display is hidden in the experience of the experts and the creativity of the artists. The question, then, is how can we make this knowledge more explicit so that we can effectively re-use it in the next design? Reflecting on the current practice of designing auditory displays is a way to understand the difficulties involved in capturing and re-using design knowledge. We approached this question by an attempt to sketch out the field—i.e. to conceptualise the field from different perspectives in order to find an organising principle for what we know, building on earlier work [7]. In order to discuss this question we organised a workshop titled "Recycling Auditory Displays" during the annual International Conference on Auditory Display (ICAD) in Paris in 2008. The aim of the workshop was to provide a forum for reflection on current practices, and an opportunity to discuss how to build effectively on each other's work. The full-day workshop was promoted through the usual channels such as mailing-lists and online resources, and took place at IRCAM[1] on 23 June 2008. A total of 16 researchers with diverse backgrounds participated in the workshop and a summary was presented on the last day of the conference. This paper presents the objectives, the structure and the results of this workshop in more detail. We conclude by discussing the major outcomes and their relevance for future work in this field.

[1] Institut de Recherche et Coordination Acoustique/Musique, http://www.ircam.fr

2. WORKSHOP

The schedule for the workshop, shown in Table 1., was structured around three main questions:

- What is it that we do, and how?
- What we know?
- How can we transfer design knowledge?

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Schedule	
09.30 am	Welcome
10.00 am	What we need - Introduction and open discussion on the current practice of auditory display design.
11.30 am	Break
13.45 am	Drawing a map - We are going to physically draw a big map of the field incorporating application domains, scientific disciplines and approaches to auditory display design.
12.45 pm	Lunch break
14.00 pm	Cornerstones - Using the map we have drawn we identify the cornerstones and the white spots, augmenting the map with papers and sounds.
15.00 pm	Break
15.30 pm	Pattern writing workshop - Practical introduction to capturing proven solutions to recurring design problems through design patterns.
17.30 pm	Reflections and closing remarks

Table 1. Workshop Program

3. REVIEW OF DESIGNS

Participants were asked to bring examples of a `good' and a `bad' sound design, and a literary reference to a cornerstone work in the field.

3.1. Design Examples (Good and Bad)

The workshop began with an introductory round in which each participant described an example of what they considered to be a good and a bad sound design, and elaborated on their reasons

for choosing them. Stephen Barrass started with two good examples of "political sonifications" chosen to show the expanding relevance and possibilities of sonification in cultural and social spheres beyond the science lab. In the first example Ben Cohen is being interviewed on a radio program about his campaign against nuclear weapons. During this interview he conveys the magnitude of the US Nuclear Arsenal to the radio audience by dropping ten thousand metal pellets onto the table to produce a very dramatic and evocative 3 minute long auditory representation of 150,000 Hiroshima sized bombs [29]. The second example is a sonification artwork by Guillaume Potard titled "Iraq Body Count" in which US military fatalities are heard as gunshots against a background texture of noise grains representing many thousands of civilian deaths, and the sinusoidal fluctuations of the world price of oil [30].

Next, Patrick Langeslag nominated the Windows Vista startup sound as a good example of audio branding and functionality. The four seconds of sound took the Microsoft Sound Design team 18 months to produce. The sound was designed in-house to avoid issues of royalty payments that arose when Brian Eno composed the Windows 95 startup sound. The Vista startup was designed to be more ambient and less disturbing than the previous Windows XP startup in order to maintain positive associations even when heard many times over [31]. Audio branding is becoming more important with cross-channel converging media. Topics of research in audio branding include human resources management through music, evaluation of acoustic brands, sound as acoustic trademark, integration of acoustic impulses into identity based brand management, the success factors of acoustic brand management, "acoustic pollution", fatigue, and the psychology of room acoustics [32].

Developing the topic of branding, Max Schneider described how mobile phone ringtones are a projection of personal identity in public spaces, and played the "sonar" ringtone on his phone as an example of the value and importance of aesthetic quality in these personal sounds.

Georg Spehr gave the mechanical sound of brushing your teeth as an example of the complexity and clarity of information that can be heard in everyday sounds. He described how good sound designs have a "contextual suitability" with clear semantic links to the context. He reiterated the previous point that sounds convey values and that good sound designs should not be obtrusive. Sound designers are becoming more involved in conveying values through the mechanical sounds produced by interactions with products, such as the "crunchiness" of a potato chip, or the "powerfulness" of a kitchen appliance.

Camille Peres agreed that good sound designs have a complexity like everyday sounds. Good sounds do not drag attention away from other activities when it is not needed, and fade into the background. A good design helps to accomplish a task. Do I need the information? The ringtone on her iPhone stands out and is identifiable in noisy places. She observed that the sound of the Trash Can emptying on the Mac Desktop is an example of a sound that is not very useful.

There then followed a discussion about sounds that were not considered such good examples of design. The reversing alarm in a Mercedes car beeps to convey that there is an obstacle behind the car. However it is really just an alarm. The functionality of this sound could be improved by providing more continuous distance information, and more contextual clues. There is potential for a much more aesthetic design than the beeping tone that could encode Mercedes branding values. This approach could be extended to the beeping sounds of Microwave ovens and other electronic appliances around the home. Manuela Maier gave the example of the tonal motifs triggered by opening and closing doors on the Paris metro as another example of a sound that could convey more useful information than just a simple warning.

3.2. Recommended Literature

In the next phase the participants each presented a paper that they found inspiration and would recommend to others as a point of reference. Camille Peres recommended a paper on the Shoogle interface in which naturalistic sounds of shaking different objects around inside a box provide information about incoming SMS messages on a mobile phone. There are eighteen impact types, including ping-pong balls hitting wood, candy rattling in jars, keys jangling and water sloshing in bottles. These impact sounds provide a wide range of distinctive timbres, and the size of the impact is intuitive to understand. IN one example application materials are linked to the meta-data of an SMS message such as sender group (work, friends, family, unknown, etc.), to produce categorically different timbres [34][35].

Camille also recommended a paper on an experiment that provides empirical support for the hypothesis that people can hear useful information about abstract data in sonifications. The subjects in the experiment were asked to predict the direction of the stock market from a sonification, visualization and combined displays. The results show 70%, accuracy from the sonification, 60% from the visualisation, and 70% from the combined display. The subjects commented that the sonification provided short-term dynamic information whilst the visualisation provided longer-term context, and sometimes these two sources were in conflict. These results raise issues about the conflict, redundancy and complementarity of multimodal displays. This paper also raises issues about the generalization of results from specific designs - for example a different sonification may not have produced the same results. [3].

Following on from this Stephen Barrass nominated the seminal study by Gregory Kramer and Tecumseleh Fitch that proved that subjects could monitor the vital signs of a simulated patient with an auditory display. The subjects in this experiment also performed better with the auditory than with a visual display [42]. These examples and studies provide evidence that sounds can be designed to provide much richer and more useful information than the alarms and feedback beeps found in most products and interfaces today.

Manuela Maier recommended Barrass's thesis on Auditory Information Design [19] as a resource for sound designers interested in providing more useful sounds in products. This thesis presents a user-centred method for designing sonifications, starting from a task scenario, followed by an analysis of the information requirements, and a mapping to a perceptually based sound space. Patrick Langeslag described the need for sound designers to have a better understanding of auditory perception research and recommended a paper on the neural basis of music perception [28]. This article gives an overview of recent developments in music cognition, and describes a model of the neural modules involved in music perception, that incorporates information about the time course of activity, and where in the brain these modules may be located.

4. MAPPING THE CURRENT STATE OF THE FIELD

The next session of the workshop was focused on mapping the current state of the field of auditory display. The session was loosely guided by, and modeled, on the "World Café" technique for "making collective knowledge visible" [37]. Four A1 size

posters were placed on tables around the room along with pens for writing and drawing on them. The posters were labeled Applications, Techniques, Users and Environments to reflect the themes that emerged from the introductory round of discussions. The participants then gathered around each poster and brainstormed by writing words or phrases that were triggered in their minds by the theme label and the other entries to produce a set of collective mind-maps. It soon became apparent that there were some items that did not fit under the existing themes and a catch-all Other poster was added. After 30 minutes everyone had circulated around all the posters and made whatever entries they felt were relevant. After a break they were then asked to return to the posters and attach blue post-it notes with references to relevant publications. The mind-maps of the knowledge that was collected are presented in the following sub-sections.

4.1. Application Map

The entries on the theme of Applications that were collected from the workshop participants are shown in the Applications Map in Figure 1.

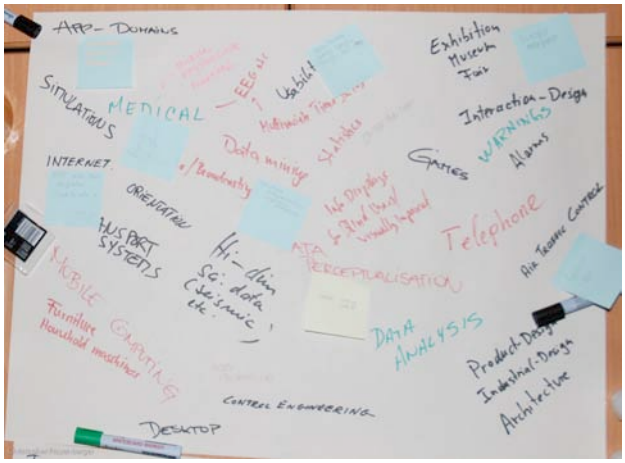

Figure 1. *Applications Map*

The references on the blue Post-its are:

- The CLOSED project [44]
- Barra, Personal Webmelody [46]
- Barrass, Auditory Information Design [19]
- Brock and Ballas [48]
- Dombois, audification [49]
- Watson and Sanderson [64]

The entries written on the Applications Map have been analysed by grouping them into Categories in Table 3.

Categories	Entries
Analysis	Multivariate time series Seismic data EEG data High dimension scientific data Statistics Data mining Data analysis Data perceptualisation Simulations Human physiological functions
Professional	Internet Medical Transport systems Air traffic control Control engineering Broadcasting
Mobile	Orientation Mobile computing Usability Information displays for blind and visually impaired users
Public	Exhibition Museum Fair Entertainment
Domestic	Furniture Household machines Telephone Home
Design	Interaction design Product design Industrial design Architecture
Alarms	Warnings Alarms

Table 3. Applications grouped into Categories

4.2. Techniques Map

The entries on the Techniques Map are shown in Figure 2.

Figure 2. *Techniques Map*

The references on the Post-its are listed below, with our best efforts to decipher them:

- Koelsch and Siebel, Towards a neural basis of music perception [28]

- The CLOSED project [44]
- Berdahl et.al., Practical Hardware and Algorithms for Creating Haptic Musical Instruments [47]
- Hayward, Listening to the Earth Sing [52]
- Hermann, Sonification for exploratory data analysis [53]
- Lerdahl, Timbral Hierarchies [55]
- McAdams/Cunible, Perception of Timbral Analogies [56]
- Suied et.al. Toward a sound design methodology: Application to electronic automotive sound [61]
- Tardieu et.al. study of soundscapes in train stations [63]
- "Slurpy sound" to warn of nearly empty gas tank
- Sonification of a histogram while playing sound
- granularity mapping
- EEG/MRI
- GPS timing for visual map ??

The Techniques have been clustered into Categories in Table 4.

Categories	Entries
Mapping	Sonification x 2 Audification x 2 Parameter mapping Model-based sonification Stream-based sonification Recordings/samples/concrete
Technology	Headphones Speakers Speech synthesizer Music synthesiser Digital signal processing Mechanical instrument Electric instrument Virtual instruments
Design	Collaborative Generative Design methods Supporting Visualisation or replacing it?
Perception	Perceptual alignment Perceptual scaling Auditory Scene Analysis Ecological soundscapes
UI	Earcons Spearcons Auditory icons
HCI	User centred Task oriented Data sensitive
Interaction	Tracking Haptics for interfaces Interaction with auditory display
Cognition	Schema Metaphor

Table 4. Techniques grouped into Categories

4.3. Users Map

The entries on the poster labeled Users are shown in the Users Map shown in Figure 3.

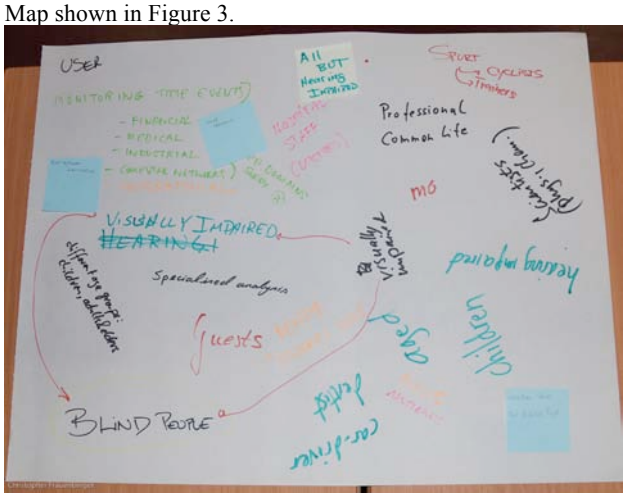

Figure 3. *Users Map*

The references on the blue Post-its are:

- The Audible Past by Jonathon Sterne [39].
- Peep network Auralization [41].

The written entries have been grouped as Categories in Table 2.

Categories	Entries
Professions	Doctors Dentists Hospital Staff Financial Industrial Geographical Computer networks
Training	Me Guests Public Amateurs Common life Develop listening skills
Ages	Children x 2 Adult Aged Elders
Ablement	Visually impaired x 2 Blind people Hearing impaired All but hearing impaired
Activities	Sports Trainers Cyclists Car-drivers

Table 2. Users grouped into Categories

The first reference is to The Audible Past by Jonathon Sterne [39], which describes different ways of listening and kinds of listeners. The book "blends cultural studies and the history of communication technology, following modern sound technologies back through an historical labyrinth. The book will interest those in cultural studies, media and communication studies, the new musicology, and the history of technology" [40].

The paper on the Peep network Auralization tool describes a user-centred and task-oriented approach to sonification [41]. "Peep enables system administrators to detect common network problems such as high load, excessive traffic, and email spam, by comparing sounds being played with those of a normally functioning network. This allows the system administrator to concentrate on more important things while monitoring the network via peripheral hearing".

4.4. Environments

The entries on the Environments Map are shown in Figure 4.

Figure 4. *Environments Map*

The references on the Post-its are:

- Sonic Interaction Design COST action [44]
- Ballas, Common Factors in the Identification of an Assortment of Brief Everyday Sounds [45]
- Gaver, What do we hear in the World? [19]
- Russolo, Art of Noises [57]
- Schafer, The Tuning of the World [58]
- World Soundscape Project [59]
- Contributions by Brigitte Schulte-Fortkamp, e.g. [60]
- old phone ringtone, iPhone. ??

The Entries on the Environments Map have been clustered into Categories in Table 5.

Categories	Entries
Professional	Computer Work space Meeting Hospital High tech Informations
Domestic	Bedroom Bathroom Living room Dining room
Public	Theatre Museum Entertainment ATM
Architectural	Room Building Area
Transport	Car Traffic Train
	Public transport Pedestrians
Military	Collaborative High stress High cognitive load
Outdoors	Sports Nature Mobile
Perceptual	3D Cocktail party problem Dense rich soundscape
Virtual	Immersive VR
Cultural	Cross-cultural x2
Personal	Personal space
Educational	Visually impaired students

Table 5. Environments grouped into Categories

4.5. Other

The entries on the Other Map are shown in Figure 5.

Figure 5. *Other Map*

The References on the Post-its are:

- Chris Frauenberger - Recycling Auditory Displays
- Gamma et.al., Design Patterns: Elements of Reusable Object Oriented Software [50]
- Sterne, The Audible Past [39]

The entries on the Other Map have been clustered into Categories in Table 6.

Categories	Entries
Affect	Affective Emotive Aesthetics Auditory past Pollution Art
Design	Repurposing Design patterns Implicit design knowledge Interactive optimisation of parameters
Legal	Hacking Copyrights

	Copyleft Intellectual property
Perception	Tactile (fingertip) Sensation (via spatial) sound
Social	Social media – e.g. manyeyes.org Community of practice
Cultural	emic / etic Bridging artistic and science disciplines
Personal	Personalisation

Table 6. Other grouped into Categories

5. DESIGN SPACES

The final session began with Chris Frauenberger's proposition that design practice needs to be described in a way that makes hidden knowledge explicit so that we can reuse what we know. He presented the idea of Design Patterns that has been used in many disciplines to capture design knowledge. Design Patterns were first developed by Christopher Alexander as a method for participatory urban design [43], but rose to prominance in software engineering as a way to reusing existing code [50]. Sonification Design Patterns were introduced into Auditory Display by Stephen Barrass in 2003, but there has only been limited activity on the wiki site since then. Chris Frauenberger and colleagues have developed a higher-level framework called **paco** – pattern design in the context space - in order to promote the use of patterns as a way to capture and reuse design knowledge in the auditory display community. **paco** is unique because it provides contextual relations between design patterns and design problems. The context space is an organizing principle that links artefacts, examples, patterns and design problem through common contextual properties and aims to provide the designer a tool to conceptualise the design space [7]. An interface to the collection of patterns allows the user to overview and zoom in on the network of connections between patterns, and edit or add new patterns online with links to associated resources such as publications, youtube videos or soundfiles.

The description of paco sparked a discussion about design spaces that describe a shared body of knowledge. Thomas Hermann described another tool for constructing and navigating a database of designs, called the Sonic Interaction Atlas (SIA) [44]. Like paco, the interface is a visualisation of relations between designs annotated by tags that describe tasks, interactions, and sounds. The visualisation of network connections is constructed from the tags and can be searched by filtering on tags.

The visual representation in the Data Sonification Design Space Map (DSDSM) is a continuous 3D space that describes the range of all possible designs within the axes of definition, rather than individual design points. Like the other design spaces it too is intended to make implicit knowledge (often expressed in 'natural' ad-hoc decisions by sonification experts) explicit and thus available for reflection, discussion, and learning [de Campo 2006]. The designer or researcher can use the space to engage in systematic reasoning about different sonification strategies based on data dimensionality and perceptual concepts that specify locations on the axes. Techniques labeled as Discrete Point, Continuous and Model-based are depicted by regions bounded by the Perceptual and Data axes.

The session ended with broad agreement that the community would benefit from overviews of design spaces and we discussed future lines of research based on the work that was presented.

6. DISCUSSION

In the introductory discussion the participants repeatedly mentioned aesthetics and the need to strike a balance between non-disturbing, but informative sound properties. This makes an interesting link between the artistic perspective and the management of attention in auditory display design. Both areas offer approaches (e.g. [7], [8]) to design for auditory display, but bridging the gap between them seems crucial for good design. Other qualities revealed by the discussions include contextual suitability, simplicity, semantic connection to the real-world and the power of audio to attach values to a presentation. At the end of the session the key areas of common interest for further discussion and investigation were identified as Applications, Techniques, Users and Environments. A final catch-all Other was added early during the Mapping session.

The participants made more than 150 entries and attached more than 30 post-its with references during the workshop. The collected information is summarised in Table 8. which shows number of entries for each Map in column (E) and the number of references in column (R). There were more than 30 entries (E) in Applications, Techniques and Environments, and more than 20 in Users and Other. The number of references (R) follows a similar pattern with most references for Techniques (13) and fewer for Users (2) and Other (3). These distributions draw attention to the areas of focus in the field. While we had little trouble to define our discipline through Techniques and Applications, there has been less research into other aspects that have been identified in this workshop. This indicates that there is the need to bridge the gap between contextual aspects and the design techniques of auditory display.

The last columns in Table 8. show entries grouped into Categories. Column (C) is the number of Categories in each Map, and the last column lists Categories in order of number of Entries (shown bracketed). The analysis of groupings was a subjective process and is not intended to be definitive. However this process provided insights into the data and a basis from which to begin to theorise. The highest number of Categories is 11 for Environment, while the lowest is Users with 5. Categories that appear across different Maps are shown **bold.** The main categories of overlap are **Profession, Design** and **Perception** which appear in three maps, and **Domestic**, **Public Culture** and **Personal** which appear in two.

Map	E	R	C	Categories
Applications	35	6	7	Analysis(10), **Professional(6)**, Mobile(5), **Domestic(4)**, **Public(4), Design(4)**, Alarms(2)
Techniques	32	13	8	Mapping(8), Technology(8), **Design(4), Perception(4)**, HCI(3), UI(3), Interaction(3), Cognition(2)
Environments	32	8	11	**Professional(6)**, **Domestic(4)**, **Public(4)**, Architectural(3), Transport(3), Military(3), **Perception(3)**, Virtual(2), **Cultural(2)**, **Personal(1),** Educational(1)
Users	26	2	5	**Professions(7)**, Training(6),

				Age(5), Ablement(4), Activities(4)
Other	22	3	7	Affect(6), **Design(4)**, Legal(4), **Perception(3),** Social(2), **Cultural(2)**, **Personal(1)**

Table 8. Comparison of Maps.

The Applications Map has the most entries which is not surprising given that Applications has been a frequent session topic in ICAD conferences over the past decade. Most of the entries are about analytical, professional, or mobile applications, and so are the references. However there are also applications in products, households and leisurely activities that are newer areas for research.

The Techniques Map has the highest number of references. The prevalence of Mappings(8) and Technology(8) reflect central threads in the ICAD community. However there are emerging areas of interest in collaborative and social methods for design, and that draw on cognitive and semiotic theories. The references in this section are very diverse and range through many different application examples.

The Environments Map has the highest number of Categories. The appearance of **Public**, **Domestic** and **Professional** in both Applications and Environments may indicate some confusion between "application environment" and "environmental context" that may be rectified by relabeling Environment as Context in future. Overall this map highlights the range of different contexts in which an auditory display may be used, and the need for designers to consider the effect of the context. The references to Russolo and Schafer provide important connections to the history and culture of sound and sound arts in the 20th Century.

The Users map has a lower number of entries, the lowest number of references, and the lowest number of categories. This is an area that has not received much attention in the ICAD community. The research on Users in the ICAD literature has so far been limited to the classification of experimental subjects by gender, age and musical training. Subjects in experiments are usually between the ages of 20 and 40 and take a test to ensure normal hearing. The Categories in the Users Map distinguish two main kinds of Users. The first are Users with listening abilities that vary with training, age, and ablement. The other is Users with different skills who are involved in different tasks.

The Others Map has the lowest number of entries and low references. It contains mainly concepts that participants felt were important for the field, but would not fit into one of the other Maps. These included aesthetics, intellectual property rights and personalisation. Some entries directly addressed design issues, such as community of practice, role of anthropology, implicit design knowledge or design patterns. The culture category raises the issue of different approaches in the humanities and sciences summed up by the entry on "emic vs etic". In product advertising an emic approach is culturally specific (for example McDonald's makes an Aussie Burger with beetroot on it in Australia but nowhere else), whilst an etic approach is the same in every country (Starbucks has exactly the same range of coffees in Australia as in France).

A summary and initial analysis of the outcomes of the workshop were presented in the final session at the end of ICAD 2008 on a grid with the axes "what we know/ don't know" vs "what is known / not known", shown in Diagram 1.

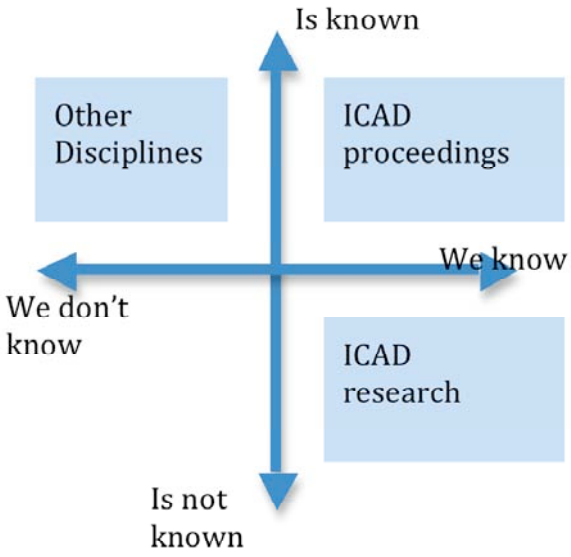

Diagram 1. What we know vs What is known

The top right quadrant "What we know is known" is the existing knowledge in the ICAD proceedings, designs, and related literature that has been integrated into to the field. The quadrant below it labeled "What we know is not known" is the area of future research specific to Auditory Display that builds on the existing knowledge in the previous quadrant. The quadrant "What we don't know is known" is relevant knowledge from other disciplines such as psychoacoustics, HCI, psychology, neuroscience, design, sound art, and so on, that has not been integrated into the ICAD knowledge base as yet. An example is the entry on "etic vs emic" that is outside the current vocabulary of Auditory Display, and the references to literature of Sound Art History and Culture also lie in this region. The final quadrant quizzically titled "What we don't know we don't know" is the blind spot where radical paradigm shifts in knowledge can occur. We hope that by mapping out more of the other areas around it we can provide more links to crossover into this region.

7. CONCLUSION

The aim of the RAD workshop was to capture knowledge about the design of auditory displays from the participants in a manner that would be easy to understand and reuse. The workshop began with the participant's examples of good and bad designs that have been described here, and a handful of suggested references. Much of the discussion around these focused on culture, identity, aesthetic and contextual issues that are more aligned with product sound design than the technical and application oriented directions in auditory display research. Based on these discussions the labels Users, Applications, Techniques and Environments were chosen to focus further development of ideas in a collaboratively mindmapping session. It was soon realized that an additional catch-all poster labeled Other was also needed to capture the emerging issues. The 5 Maps captured more than 150 entries and 30 references that are shown and transcribed in this paper for others to interpret. The entries were classified into 25 Categories that denote different issues to consider in auditory display design. The analysis of the entries has highlighted that the bulk of knowledge about design in auditory display has been focused on applications and

techniques, which have been the core of the field since its inception. The Users Map and the Others Map provide an insight into the fringes of auditory display on the border with other disciplines such as product design, cultural studies in the sound arts, auditory perception, semiotics, and HCI. The Environment Map also provides directions for future research that incorporates contextual issues into the existing body of ICAD knowledge. In the end the entries in the Maps were not problems with good solutions that could be captured as design patterns as was originally envisaged. The primary outcome of the workshop has been to collaboratively understand and Map out what is known about design in the Auditory Display community, and based on the diversity of understandings, point to areas where it would be most beneficial to know more.

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