EMBODIED COGNITION IN AUDITORY DISPLAY

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ABSTRACT

This paper makes a case for the use of an embodied cognition framework, based on embodied schemata and cross-domain mappings, in the design of auditory display. An overview of research that relates auditory display with embodied cognition is provided to support such a framework. It then describes research efforts towards the development this framework. By designing to support human cognitive competencies that are bound up with meaning making, it is hoped to open the door to the creation of more meaningful and intuitive auditory displays.

1. CONTEXT

Auditory display is a relatively new inter-disciplinary field that, although having made some very serious advances since its inception, still remains a far cry from the status of its visual counterparts. In its current state it exists against a backdrop of open questions and problems. The biggest question is why its development has stalled and how can it be promoted in a way that presents auditory display as a useful contemporary method for the rendering of data to cognition. In answering that question it has been proposed that there is a need for an overall theoretical framework for auditory display in which to position research and development efforts. The need for this framework is brought up by Walker and Nees [1] who suggest that a deeper understanding of human interaction with auditory display is also needed. This second point is especially interesting to the authors, and it is stated once again by Neuhoff and Heller [2] who go one step further and call for the development of auditory display based on intuitive mental models. Their idea is to design for pre-existing cognitive competencies. This sentiment is repeatedly reflected across the literature. There seems to be an emerging sense that the development of an overall theory of auditory display will have to give serious attention to cognitive factors. Gossman [3] makes a similar call, but with a specific slant towards embodied cognition, and Walker and Kramer [4] isolate cognitive processing as a key component for consideration in sonification.

Auditory display exists at the intersection between a myriad of other disciplines such as auditory research, human computer interaction, music technology and cognitive science. The task of establishing auditory display as an independent field in its own right requires a grounding theoretical framework.

In order to do this, it is necessary to get a deeper understanding of how users interact with auditory displays. More study that is directly focused on cognition in auditory display is needed. Much of the cognitive research that is referenced in the field has been borrowed from similar and related, fields. With such a framework in place some of the obstacles specific to auditory display may be approached. Some of these problems, such as the need for more aesthetically pleasing and meaningful displays, are a constant concern driving research and development efforts within the field. The development and exploration of model based sonifications is a contemporary concern, as is the development of more intuitive earcons that do not rely so heavily on previous learning; the extensions of auditory icons to emerging interactive mobile technologies, and the prevention of entanglement between factors of auditory perception and data-relations in parameter sonification.

In order to advance the field, it is necessary to undertake a more rigorous examination of how people interact with auditory display systems.

2. THE ECOLOGICAL APPROACH

J.J. Gibson pioneered the ecological approach to perception. This states that an organism's actions are constrained by the affordances granted by its environment. In auditory display, this necessitates the design of environments (display) that offers certain affordances to the user. This has been a useful approach and thinking of this sort has underpinned much of the development in the field [4],[5] [6], [7], [8], [9], [10]. It is here argued that the ecological approach answers half of the question of how to design meaningful and salient auditory displays. It takes as its point of departure the notion of naïve realism, that the senses offer us a direct awareness of the exterior world. This assumption does not account for the nature of human embodiment. For auditory displays to take that leap forward into the realm of everyday usefulness, it must be accepted that the environment from which affordances arise is organized by our cognitive capacities. Taking into account Varela's [11] notion of enaction, i.e. cognition as the process of guided action, the concept that an environment is shaped by both the physical world and the biological systems of the organism emerges. This paints a picture of an environment that is both a product of cognitive capacities, and of physical matter. In extending the notion of an embodied sound environment to the auditory display user, a wider range of affordances (based on the embodied, as well as the physical, nature of their environment) is offered. This permits a consideration of certain cognitive capacities, which will be discussed later, as channels across which affordances that are rooted in our meaning-making capacities can be offered. The affordances offered by the interplay of cognition and environment are here referred to as embodied affordances.

3. THE COGNITIVIST PARADIGM

Cognitivism is a model of human cognition which states that (i) The mind works like a computer, (ii) The world is represented to cognition via arbitrary symbols, and (iii) Thinking is computation [11, p.52-57]. A thorough study of the prevalence of cognitivism within the field of auditory display is well beyond the scope of this paper. As such, only the reason for rejecting this paradigm before exploring our alternatives will be presented.

In its framing of cognition as the relation of arbitrary symbols to features of physical reality, cognitivism fails to account for meaning-making in any convincing way. This is called the symbol grounding problem [12]. Any attempt to understand human interaction with auditory phenomena will necessarily concern itself with meaning. The explicit aim of the project presented here is to create a framework for more meaningful data-to-sound mappings in auditory displays. Any theory of mind that fails to account for meaning-making cannot be accepted.

4. EMBODIED COGNITION

The alternative chosen for exploration, is the notion of embodied cognition. It is a rapidly expanding research program focusing on the role of the body in cognition [11]. It offers new understandings for the perception of sound and music [13, 14]. According to numerous sources, including Lakoff & Johnson [15, 16], Freeman & Nunez [17] and Lakoff [18], embodied cognition proposes a more cohesive and accurate portrait of cognition than its alternatives. As will be seen later in this paper, it also provides an answer to the symbol grounding problem by rooting meaning in bodily experience. Through study of the bodily correlates of cognition, the basic cognitive capacities by which meaning is created, and sense is made of one's world, have been uncovered by embodied cognition researchers. These are:

1. Affective/kinaesthetic dynamics
2. Conceptual Metaphor Theory
3. Sensorimotor mimesis
4. Embodied Schemata
5. Conceptual Blending.

Broadly speaking, these low level constituents of cognition derive from sensory-motor activity (resulting from our embodiment) and organize our cognitive experience (in terms of that embodiment). These capacities have been explicitly shown to account for the application of meaning to music and sound patterns [14]. For this reason an embodied cognition framework has been chosen for auditory display design, and ideas from Lakoff and Johnson's [15, 16] conceptual metaphor, and embodied schemata theories have been isolated as points of focus. These explicit topics have been chosen as not only are they theoretically relevant to meaning-making, but there is a strong body of empirical research that documents their operation [18].

5. EMBODIED COGNITION AND AUDITORY DISPLAY

As is about to be discussed, the application of an embodied cognition framework in a computer science context is not new. The idea of applying such a framework to auditory display is not very new either (as shall be similarly discussed). This paper is arguing for such an application at the mapping level in the sonification process. This approach is new and is discussed later in this paper.

The seeds of recent research trends were planted by Paul Dourish's [19] "Where the Action Is". This book marked something of a sea-change in human computer interaction (HCI). Strongly grounded in embodiment philosophy, it encouraged designers to focus on something called "embodied interaction" when designing interactive systems, and provided a range of design principles to facilitate just that. Embodied interaction is the union of social and tangible computing so that the physical world may be used as a medium for interacting with digital technology. It is "the creation, manipulation and sharing of meaning through engaged interaction with artifacts" [19, p126]. An embodied interface is any interface that allows the conversion of action into meaning.

Much research relating embodiment to auditory display draws on Dourish's ideas of embodied interaction. For example, Rath & Rocchesso [20] and Rocchesso, Polotti, Monache [21] consider "continuous sonic interaction" in terms of an "embodied interface". Focusing on embodied interaction, DeWitt & Bresin [22] isolate embodied and ecological approaches to sonic interaction design in an attempt to utilize sound design as a form of affective interaction.

Wakkary *et al.* [23] and Droumeva & Wakkary [24] have explored embodied interaction in auditory display within the context of an ambient intelligence game. They root their approach in Dourish's embodied interaction as do Droumeva, de Castell & Wakkary [25] in their consideration of learning through embodied interaction in the context of auditory display. Droumeva *et al.* [26] linked embodied schemata and embodied metaphor with sound feedback in the context of auditory display. This project was concerned with interaction and, as such, drew from embodied interaction again. It was their take on feedback that caught the imaginations of the current authors. Auditory feedback in an interactive system (called Springboard) was organized in terms metaphorical extensions of the balance schema. Through a process of "cross-domain mapping" (which will be elaborated upon in this paper) people were then able to reason about the auditory content in terms of balance. Research of this form highlighted the inherent potential in organizing auditory displays for cognitive capacities.

Diniz *et al.* [27] have explored embodied music cognition strategies for making multi-level sonifications both meaningful, and easy to understand. Much of this work was based on Leman's [13] embodied music cognition framework, and as such does not so much rely on embodied interaction directly. Brazil & Fernstrom [10] also depart from embodied interaction, while still employing an embodied cognition framework. They conducted experiments on the recognition of concurrent auditory icons that were rooted in the theories of prominent embodied cognition researchers such as Lakoff & Johnson [16], and Varela *et al.* [11]. Peres & Byrne [28] sketch out their "Interactive Behaviour Triad" for auditory graphs that, although dealing with embodied cognition and interaction, does so in a way that frees it from the notion of embodied interaction.

All in all, there is an excellent body of research testifying to the usefulness of embodied cognition as a framework for the design of auditory display. This research is here referenced in order to legitimize the current research. The project reported on here is not concerned with embodied interaction or embodied interfaces *per se*. It deals with how our bodily nature provides certain cognitive affordances for the interpretation of elements of an auditory display. As such, it is necessary to consider some of the cognitive capacities discussed earlier in order to establish how exactly a project of such a nature can be embarked on.

6. CONCEPTUAL METAPHOR AND EMBODIED SCHEMATA THEORY

Conceptual metaphor theory, or CMT, as introduced by Lakoff and Johnson in “Metaphors we live by” [15] claims that a large portion of human concepts are composed of “metaphorical” projections or mappings from a source to a target domain. A domain in this case is interpreted as any cogent assembly of human experience. Johnson [29] argues that meaning arises from these cross-domain mappings.

Human conceptual organization in terms of CMT is probably most readily identifiable in linguistics, where phrases like “my stocks are rising” and “the mood was quite heavy” represent underlying cross-domain mappings from bodily experiences to conceptual instantiations. However, it has been conjectured that cross-domain mapping (Figure 1) stretches beyond linguistic device, and is the basic methodology by which we reason.

Conceptual mappings need not always be between embodied experience and abstract concepts. There are many examples of cross-domain mappings from concept to concept. It is mappings from embodied experience to abstract concepts which allow CMT to overcome the “symbol grounding problem” [12]. These mappings root the “meaning” of conceptual content in one’s embodied experience by way of “embodied schemata”.

Embodied schemata are the recurring patterns of our sensory-motor experience by means of which sense can be made of that experience, and it can be reasoned about. Embodied schemata can also be recruited to structure abstract concepts, and to carry out inferences about abstract domains [29].

The internal logical structure of these directly meaningful, pre-conceptual, cognitive primitives may be metaphorically projected from the sensory-motor to abstract conceptual domains. This cross-domain mapping provides the internal logical structure for concepts, imagination and human reasoning [30].

They are not instantiated by any neural module but, rather, are recurrent patterns of sensory-motor activity, in consistent correspondence to recurrent experiential patterns. As such they call for a definition within a space that is more akin to Dewey’s body-mind than to modern ideals of strictly “mental” or “physical” domains. According to Johnson [30], embodied schemata are constitutive of all domains of human experience conceptual, perceptual and affective.

It is important to note that it is embodied human experience itself, and not embodied schemata that are considered the basic building blocks of conceptual domains. These domains are structured by embodied schemata, and it is this structuring, not the content, that can remain invariant from one domain to another. It is on this basis that reason can be pursued. This is expressed in the invariance principle which will be discussed later.

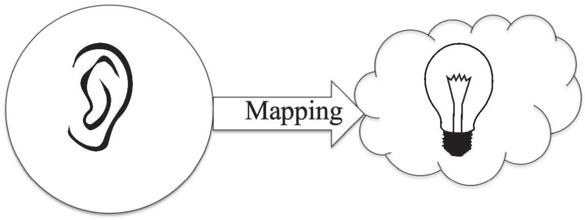

Figure 1: Cross-domain Mapping in CMT

7. EMBODIED SCHEMATA AND CROSS-DOMAIN MAPPINGS IN AUDITORY DISPLAY

Embodied schemata and cross-domain mappings have attracted interest across a range of disciplines, and are not new in the field of auditory display. Lakoff’s CMT has long been a topic of interest in sonification design [31]. Metaphor is by now integral to the field of HCI in general [32]. Where not explicitly mapped from some metaphor themselves, auditory icons and earcons are often used to reinforce such metaphors in an auditory display [33],[10]. Metaphor and cross-domain mappings are central issues in sonic interaction design [34] and are widely used across general auditory display [35] [36] [37] [38]. Antle, Corness & Droumeva [39] provide another study from a project named Soundmaker (which will be discussed shortly) that shows how embodied schemata and metaphor theory can be used to design salient feedback in an auditory display environment. By making a subconscious embodied schema (balance) conscious via a metaphor, the users were better able to reason about an interactive system as well as its auditory feedback. This is a good example of designing directly for our cognitive capacities in an auditory display and the result, i.e. greater salience, is encouraging.

Embodied schemata and cross-domain mappings (metaphors) provide an extremely well-suited framework for intuitive design [39], [40], [41], [42], [43]. They also prove to be well-suited to the design of more meaningful auditory displays, where audio signals are of a higher level of salience [26].

Antle *et al*. [44] have offered a set of empirically grounded design guidelines that rely on embodied metaphor and embodied schemata to facilitate reasoning as it is envisioned to take place within the embodied paradigm. The guidelines were developed from a review of three research projects. The Soundmaker is an interactive audio environment that makes use of an embodied metaphor to map movement to sound. It was envisioned as a more mobile take on the Moving Sound Tangibles project. Tangible objects are used as sound generators, emitting sonic information during interaction in keeping with a central embodied metaphor. The third study is the Springboard interactive environment (discussed earlier) which uses metaphor and cross-domain mapping to facilitate one in reasoning about an interactive audio environment. These projects are audio related. All three rely on auditory display to relay meaningful information to a user, and all three have found that the use of an embodied cognition framework with a focus on metaphor and embodied schemata can facilitate users in understanding and reasoning about auditory display.

8. EMBODIED SCHEMATA AND METAPHORIC REASONING

An important entailment of the embodied mind thesis is that all mental activity, imaginative or rational, must arise from the states and activities of the body in which it is associated. The theory that designing for latent cognitive capacities can facilitate reasoning emerges repetitively across the intersection between embodied cognition and auditory display literature.
According to Lakoff and Johnson's [16] "invariance principle", metaphorical mappings between domains retain the embodied schematic structure of the source domain in the target domain. It is the invariance of embodied schematic structure from one domain of human experience to the next that enables an ability to reason about and understand these domains. This explains the ability to understand and reason about seemingly arbitrary and abstract domains. It simply involves mapping their logical structure from domains of greater familiarity. All of these mappings ultimately lead back to the basic domain, from which embodied schemata are acquired, i.e. embodied experience. In short, to reason is to reason about one thing in terms of another, and that is achieved through cross-domain mapping. The rules governing reasoning are taken from the rules governing bodily experiences in, and bodily experiences of, environments.
For example, elements of logical (rule-based) structure from a domain of human experience such as "getting from a to b" can be mapped to provide some internal structure for an abstract domain like project management. Project management can then be reasoned about based on the logic of embodied experiences of moving from one place to the next. For example, if workflow is speeded up, the end of the project should be reached faster, just as a person reaches their destination faster when they speed up their movement. If work is stopped, or gets side-tracked with another project, the destination will not be reached. This simple mechanism of cross-domain mapping lies at the beating heart of human reasoning and imagination. It explains how it is possible to reason or imagine at all on both conscious and subconscious levels.

9. CONTRIBUTION OF CURRENT RESEARCH

It has already been discussed in the previous sections that the paradigm of embodied cognition has been visited by multiple researchers working in the space of human computer interaction and auditory display. The concept is of great interest for the current research effort as it seems that it has been effectively applied to auditory display in the recent past. Rather than employing this within the context of an interaction however, it will here be broached from the other end. The current study will concern itself purely with the auditory element of auditory display, focusing on the use of embodied schemata and cross-domain mappings to increase salience and understanding. Hopefully it has been shown here that there is already a strong body of knowledge concerned with embodied cognition as it applies to auditory display.
It is proposed that a study of this nature offers a more user-centered approach to auditory display, where the focus on designing for the users' cognitive capacities leads to more meaningful auditory displays. With this project it is hoped to make a contribution of value to the field. The embodied framework is grounded in principles of modern cognitive science that have already shown promising empirical results when applied to design issues in auditory display. It is anticipated that such a framework will facilitate contributions towards solving the following problematic areas in the field:

- The creation of more intuitive and meaningful sonifications [45].
- The need for more cognitively based research [46].
- A contribution towards the survey of cognitive processing in the field [4].
- The use of pre-existing cognitive structures to interpret sonified changes in variables [2].

10. THE APPROACH

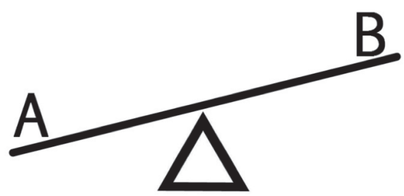

Figure 2: Twin-pan balance schema.

This project will focus on modelling the internal logical structures of sets of embodied schemata in the auditory domain. The design metaphors that are used for these models are the embodied-schemata themselves. Different individual embodied schemata accomplish different types of reasoning and importantly are common across all who share human bodies. This is significant in that it grants image schemata a level of invariance and general relevance across populations. By making these implicit systems of reasoning explicit, the auditory models will, or so the literature states, facilitate specific modes of reasoning about their data inputs. This reasoning will be constrained by the embodied schema from which each model derives. Simply put, the embodied auditory models used should invite the listener to consciously reason about variables in an auditory display using the same cognitive strategy by which they subconsciously understand those variables. This should make for much more meaningful auditory display elements. Through the development and study of these models, an embodied auditory design framework will be built. This will aid in the creation of meaningful auditory displays. It will also aid future research and development of embodied cognition applications in sound design and more generally.
To better understand this approach, consider an example of a parameterized model that is designed in accordance with the logical structure of the twin-pan balance schema (also used in the Springboard project.). Two data inputs are mapped to two sound objects at equidistant placement on the X and Y axes in auditory space. Increase or decreases in the magnitude of the two data inputs may be mapped to pitch, timbre or other salient attributes of the two sound objects. This embodied auditory

model can be used to tell people something about the relationships between two "variables". For example, where A and B represent volumes, it is possible to tell people that A is larger than B, or that one value is rising while the other is falling. Different embodied schemata are better suited to different tasks. The twin-pan balance schema may be useful to represent the relationships between two magnitudes, but may not be very useful in conveying information about transformations over long time frames, for example. The source-path-goal schema is structured in terms of a source or starting point, a trajectory, and a goal or end point. Due to its dynamic nature, this schema may be much more useful for conveying data that changes over long time frames.(In fact, if serial data inputs were to be used with the twin-pan balance model, it is likely that they would be cognized as changes of state in the twin-pan model in terms of the source-path-goal schema.) The twin-pan balance schema represents a metaphorical extension of an embodied schema into the auditory domain, and can be further extended by combination with other embodied schemata. The fundamental metaphor in question is based on the schema itself: twin-pan balance. This renders the unconscious reasoning process conscious, and facilitates the user in reasoning about the display. It is envisioned that a wide range of applications can be identified for this model, from spreadsheet/budgetary software to industrial process monitoring.

11. APPLICATIONS

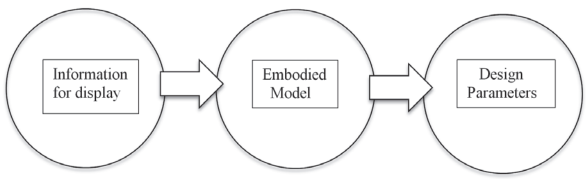

Figure 3: Design process using the Embodied Auditory Display Framework.

The framework represents a task-based approach requiring the designer to know beforehand what information they wish to convey and then selecting as a design solution the embodied model that maps that information to synthesis parameters. The embodied schematic nature of the models implies that the mappings should be meaningful to the user.

The finished framework is to consist of a set of embodied auditory models and empirically grounded guidelines for the application of each model. The auditory models themselves are logically based and can be delivered across multiple hardware/software platforms. They are currently under development and testing in Csound. Development has taken the form of an iterative design process. By testing the models in different scenarios application guidelines are also being iteratively developed. These guidelines dictate the application of the models as design solutions to challenges arising in the development of auditory display systems. The guidelines contain:

1. Initial description of the model's logic.
2. **FOR:** Data-types it can be used with.
3. **WHEN:** Cognitive tasks it is suited to.
4. **HOW:** Implementation/mapping strategy.
5. Suggested synthesis methods.

Mapping data to auditory parameters is no trivial task. A working framework of this sort should act to inform a designer's choice of mapping strategy, polarity, scaling, context and synthesis techniques in a Parameter Mapping Sonification (PMSon), as these variables are determined by the guidelines. The framework operates at the mapping level and so is intended to extend to Model Based Sonification as well as parameterized Earcons and Auditory Icons.

At present research is focusing on the development of a twin-pan balance schema model. That schema was detailed earlier in this paper. It is implicated when one compares or contrasts two domains of human experience [29]. It has also been used to structure meaningful interaction in the auditory display. The current research has created an auditory display based upon the logic of this schema.

12. DEVELOPMENT AND RESULTS

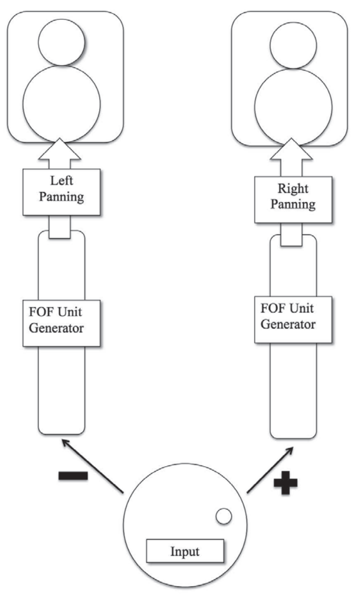

Figure 4: Model set-up for twin pan balance schema.

Multiple variations of the twin-pan balance model have been iterated using FOF synthesis techniques. The basic model set-up is straightforward. Two inversely proportional inputs are fed into FOF unit generators, and the outputs are panned hard right and left. A knob widget determines input variables with Input values mapped to the right synthesis line and their inverse (MaxInput - Input) mapped to the left line as per Figure 3. As the knob is manipulated and the right side tone rises in pitch, the left falls. The models are programmed in Csound. The display works well with headphones and through two free standing Genelec 8040A adjusted for user height.

The previous model has undergone three iterations. The aim is to create an exemplary model that maps data-to-sound dimensions in keeping with the embodied schema it derives from. This mapping model and strategies for its implementation can then be described in a set of guidelines that can be applied to find design solutions for mapping challenges in an AD system.

The following logical features were determined during the development of this model:

1. It works for either discrete or continuous data-types.
2. It can represent relations between two variables only at any one time.
3. It facilitates comparative or contrasting information (e.g. weight, height, equality and size comparisons).

A number of performance observations and predictions have been made from preliminary observations and usability testing.

For example:

1. The FOF synthesis technique may complicate perception of pitch at lower grain densities where tones become in-cohesive.
2. Equidistant panning of two similar and continuous tones may represent the schema well. Initial testing is positive.
3. Formant frequencies may affect users' understanding of a sound. It is predicted that a lower formant frequency and wider formant skirt will be understood as a larger or heavier sounding object. As a result, incoming data should be mapped to the formant, as well as fundamental, frequency of its corresponding tone when using FOF synthesis.
4. Both sounding tones must retain an inversely proportional relationship in the perceptual domain in keeping with the restraints of the embodied schema.
5. Preliminary usability testing has indicated that introducing a third sounding object with central panning (to represent a fulcrum/point of equilibrium) facilitates a more intuitive understanding of the relationship between the two primary sound objects.
6. However, this centre tone initially seems to overload the listener. It is conjectured that introducing a third tone may in fact be more suited to the cross comparison of three verticality schemas, rather than the twin-pan balance schema.

	Fundamental Frequency	Formant peak	Formant Skirt
First Iteration	Yes	No	No
Second Iteration	Yes	Yes	No
Third Iteration	Yes	Yes	Yes

Table 1: Mappings across first 3 iterations of the twin-pan balance model

In order to address the problems listed above arising from the application of twin-pan balance schema for data-to-sound mappings using FOF synthesis, more complex mappings were introduced. In the second design iteration, input values were used to modulate the formant peaks of each tone in keeping with the twin-pan balance schema where a high input value maps to a high tone, and vice versa. On the third design iteration the width of the formant skirt was also taken into account with a wider skirt being mapped to a lower input value in keeping with the logic of the twin-pan balance schema.

13. FUTURE DIRECTIONS

An embodied schema cannot provide the exact synthesis parameters that may best represent specific data in the auditory domain. What it does supply is a general set of guidelines to make those mappings intelligible and meaningful [44]. Future work will focus on exploring the viability of embodied schema for creating meaningful data-to-sound mappings in AD systems.

While the current project is focused on mapping data-to-sound, a future application of embodied schemata and cross-domain mappings to the auditory element of auditory display could potentially focus on timbre. Timbre manipulations, based on embodied schemata, could potentially be used to represent meaningful changes in an auditory display data-set. The reasoning about, and understanding of, timbre is mediated through embodied schemata and cross-domain mapping. Maybe timbre could provide new dimensions across which to code information? Walser [47] links the various “force” schemata derived from our embodied experiences with the timbral qualities of “distortion”. He chronicles the use of distorted guitar timbres in contemporary popular music to rouse feelings of force and power. Perhaps timbre could be manipulated in keeping with force schemata in order to tell a user something about force? A study of timbre would require a working knowledge of what specific information each force schema can convey. This will not become apparent until more force schemata have actually been modelled. A comprehensive study of such phenomenon would benefit greatly from the guidance of such a finished design framework as the current one. Hopefully, some insights into the use timbre for conveying information in an auditory display will also be gained in the course of this project.

In terms of wider aesthetics, Johnson [29] gives a brief, if interesting, account of Kandinsky’s understanding of colour in terms of embodied schemata. It is desired to explore the idea of structuring timbre based on embodied schemata to convey some form of information through aesthetic effect. This would require an in-depth analysis of which exact embodied schemata are bound up with which exact timbral elements. From here experimental auditory displays could be iteratively prototyped and evaluated as required in the development of a framework for timbral organization on the basis of embodied schematic principles. Such an undertaking would benefit greatly from the framework that is proposed in this paper.

14. CONCLUSIONS

In support of the current research, this paper outlined successful projects employing embodied cognition to auditory display. A case has been presented for the use of embodied cognition frameworks in the design of auditory displays and one such framework has been proposed which it is intended to further explore in future research. The aim of this research project is to address the issue of creating meaningful data-to-sound mappings within the field of auditory display through the lens of embodied cognition. An approach to achieve these aims has been presented. This approach is based on the development and study of embodied auditory models that are metaphorical recreations of embodied schemata logics, in the auditory domain. These are intended to increase saliency and facilitate reasoning in auditory display design through the creation of more meaningful mappings. The route of the current study has been briefly described and it has been speculated that a future study concerned with timbral design in auditory display should be based on embodied schemata. This project differs from other similar research efforts in the field in its shift of focus away from embodied interaction and onto embodied cognitive affordances.

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