Data Perceptualization through Affect in Dark Sonification

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Experiencing data through interactive multimodal displays for embodied cognition enables humans to explore and perceive emergent meanings through affect. Inspired by Gendlin's focusing and thinking at the edge methods, this work explores affect in the felt sense, arguing that bodily awareness while interacting with data can facilitate embodied knowledge through pre-conceptual sensory dimensions of meaning. Despite studies in Human Computer Interaction bringing attention to the benefits of focusing on the felt sense for design and interaction, its application remains rather unexplored for interactive data display. In our study, participants interacted with a toy data set displayed via Dark Sonification, an interactive multimodal data display system that is designed to explore complex data through embodied perception. In following interviews, the participants described emergent structures in data reported using sensory language, which contrasts the technical description normally used in exploratory data analysis contexts. Although the findings are exploratory, this work suggests that focusing on the felt sense for interactive data displays can be a valuable complement to traditional methods in exploratory data analysis.

1. Introduction

The field of data display has developed greatly in the past decades as an important part of information science (Enge et al. 2024, 3; Lindborg et al. 2023, 3). However, the predominant approach to data display is often presented to be experienced passively, frequently overlooking how these displays affect human perception and how affect can help uncover meanings in the data, a notion discussed by Lan and Yanqiu in their work on Affective Visualization Design (Lan and Yanqiu 2023, 1-2). In many cases, information display focuses on affect in terms of discrete and measurable human emotional states, nonetheless, interactive and multimodal data display, seen as HCI systems, can help perceive emergent meanings in data not only through emotional responses but also by attending to the felt sense (McCarthy & Wright 2004, 16).

As conceptualized by Gendlin (1978, 32-36) and articulated by Núñez-Pacheco and Poikolainen Rosén (2024, 1029), felt sense refers to a subtle, bodily awareness of complexity which entails an

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embodied knowledge that has not yet been explicitly conceptualized. Techniques such as focusing (Gendlin 1978) and thinking at the edge (Gendlin 2004) can help bring this awareness into clearer form. Accordingly, using them for interactive data displays systems can enable new insights for data exploration through affect. By drawing on Gendlin (1978, 32-36), this paper situates affect in the felt sense, as a more expansive pre- or para-linguistic affective field compared to only emotional response (Massumi 2002, 25-26, 40), to look into the human embodied lived experience for meaning-making in interactive data display systems. Below, we argue that focusing on the felt sense using Dark Sonification, an interactive data display system, can help derive meaning though affect.

Interaction plays a fundamental role in embodied data exploratory systems, such as Dark Sonification, as it can amplify the *naturalness* of the display by creating a bodily connection between humans and information elicited from data (Hermann and Hunt 2004, 5). Such systems are particularly needed in a world characterized by datafication and computation of all human areas of activity (Mejias and Couldry 2019, 1-3), where machines and humans are increasingly entangled (Sanches et al. 2022, 1-2), and decisions with global effect are being made through data insights. From this perspective, how can designers shape these systems to further stimulate an embodied understanding of data, thereby addressing accessibility and inclusion?

Prioritizing data perceptualization through affect in the felt sense could expand data access and literacy capacities empowering users to find meanings in data by focusing on inward affective shifts rather than outward conceptualization, in resonance with Petitmengin (2009, 274). The embodied perception afforded by such systems can enable other ways of knowing and understanding of data, potentially reducing the specialized knowledge threshold required to engage with data technologies (Enge et al. 2024, 8, 22). The role of aesthetics is key for these displays, as it addresses compositional, sensual, emotional, and spatio-temporal threads of experience as reflected by Heimann et al. (2023, 3) on McCarthy and Wright's (2004) conceptualization for data affectivization techniques. Similarly, intent in user design decisions is crucial for choosing the system's output and thus shaping perceptualization (Reed et al. 2024, 2). Yet, is it possible to sense data through our bodies, understanding the meanings that emerge during data exploration in the felt sense?

Núñez-Pacheco and Poikolainen Rosén (2024, 1030) describe this approach to system design as rooted in posthumanism, emphasizing the relational perspective of human-technology. Similarly, Reed et al.

(2024, 2) conceptualize them as *data-enabled artefacts*, conceiving data as more-than-human objects. Hence, interactive display under this line of thought, is a human-data co-created relational space, existing as a vibrant and active embodied environment (Núñez-Pacheco and Poikolainen Rosén 2024, 1030). By turning interaction design attention to the felt sense the designer allows these systems to reward iteration and performativity, enabling an embodied perception in a preconceptual state (Kordeš and Demšar 2021, 339, 344). Consequently, when humans stay in this felt sense during data exploration, they become open to fresh perception and conceptualization of the experience, defined as carry forward steps (Hendricks 2009, 131).

This approach puts the notion of affect in the forefront, as a method for experiencing data within interactive multimodal displays. The resulting phenomena emerging from interaction can be understood as a data-human entanglement affected by context and discourse (Reed et al. 2024, 8), reinforcing data-human relationality based on intent yet constrained by the system affordances. To enable the felt dimension of experience in these systems, data and human must become finely tuned, in what Petitmengin (2021, 175) calls an "affect attunement." Within this attunement, meaning arises from the entangled interaction as experience. In parallel with Petitmenging et al. (2009, 280-281), when attending contextually to the experience of data exploration, the human gradually synchronizes the external and internal space, consequently, deriving data insights emerges from this contextual lived experience. Then, what the human perceives is the data-human relation, and the meanings derived from data exploration are closely related to this experience.

Building on the framework of affect attunement, we conducted an experiment where a selected group followed a set of instructions based on focusing (Gendlin, 1978) and thinking at the edge methods (Gendlin, 2004) to engage in exploration with a toy data set using an interactive multimodal data display technology, Dark Sonification (explained in more detail in section 3). The goal of this experiment was to assess whether interactive data display systems can benefit from thinking design of affect in the felt sense, adding a meaningful dimension to data exploratory display systems beside the emotional and conceptual. To this end, the system aims to reinforce the multiple ways of bodily knowing, addressing the experiential dimension of knowledge (Gendlin 1970, 561-563).

Moreover, this experimental study builds on our previous work on the use of data-to-sound representation (sonification) as an interface for music composition and performance (Crozzoli & Magnusson 2024).

There, we explored our design choices guided by the project's intent to create an aesthetic sonification, and their further use as material for music composition and sound source for musical performance. With Dark Sonification, it is possible to design perceptual attributes that express the mathematical grain of a data set as the affective grain of a performance and focus on bodily shifts as compositional and performative pseudo-structures, parallel to Isadora Duncan's kinesthetic impulse to follow and create movement (Berger 1992). Furthermore, the study invites traditional exploratory data analysis to incorporate the felt sense by addressing the performative side of data exploration. Whether data perceptualization through affect focusing in the felt sense is experienced in a gallery, studio or control room, knowledge is carried forward through embodied perception of data through exploration in performativity. Therefore, one of our central questions for this study is: How do participants notice, describe and make sense of the bodily shifts that occur while exploring data with dark sonification?

2. Context

Efforts in the data display community have focused on bridging data representation capabilities with more user-friendly systems. However, this often comes at the expense of flexibility in data manipulation and customizable display possibilities (Armitage et al. 2024a, 18-20). Moreover, current tools still rely on a certain level of specialized knowledge to operate them and infer information from data interactions (Enge et al. 2024, 22-23). Thus, adding interaction capacities to the display of complex data has shown an increase in efficiency, effectiveness, and user satisfaction (Pauletto and Hunt 2009, 932), yet most of these interactive systems tend to focus on embodied cognition through affect as emotional response rather than the felt sense.

Interactive data display projects could further benefit from integrating the felt sense in design, especially looking into Human Computer Interaction (HCI) research that study the felt sense. Núñez-Pacheco & Poikolainen Rosén (2024, 1029) noted that while the felt sense has been studied in HCI from a human-centred perspective, it remains unnoticed in relation to the non-human or more-than-human agents. Correspondingly, Reed et al. (2024, 8) emphasize ambiguity and open-endedness in design to bring attention to non-human agents. Making the case in favor of recognizing non-human agency, these systems use symbolic and sensory input while preserving the flexibility for humans to co-create meaning through embodied interaction. However, a challenge to include the felt sense for data exploration is that first-person experiences are often met with skepticism in sci-

entific contexts due to their subjectivity and associated bias (Gallagher and Zahavi 2012, 6). Nevertheless, focusing (Gendlin, 1978), thinking at the edge (Gendlin, 2004), and micro-phenomenology (Petitmengin, 2006) have emerged as methods to access and distil information from the felt sense in a structured manner, yet their application to interactive data displays has remained limited.

This paper focuses primarily on the human for embodied, affective dimension of data perceptualization. Hence, creating a system that positions data and humans as co-creators in an interactive display requires an open relational space grounded in design transparency and intent. In practice, this means to render visible human intent within the design workflow and enable data to express its agency. In this context, Reed et al. (2024, 4) frame these systems as *Baradian apparatuses*, where data as a material provides clarity for the design process. Similarly, Sanches et al. (2022, 1-3) propose data-driven design based on Barad's agential realism as a way to attend to the materiality of data for design purposes. Dark Sonification adopts these conceptualizations to create a display system as a data-human relational and performative space that dissolves boundaries between inner and outer experience (Hendricks 2009, 152). Here, both human and data intra-act to co-create an enacted, entangled environment.

This vision aligns with the post-interaction paradigm in HCI, which Sanches et al. (2022, 2) describe as a shift towards designing systems for and with computing, focusing on background services that allow for interaction. This paradigm manifests on the increased entanglement between human and machine in contemporary society, where human and material –such as data– are interconnected creating ongoing and emergent phenomena (Sanches et al. 2022, 1-2). Reed et al. (2024, 5) defines designing in post-interaction as creating open-ended practices of conceptualization rather than deterministic apparatuses, allowing for dynamism and flexibility, which Dark Sonification subscribes to.

Within this framework, aesthetic decisions play a fundamental role in shaping affect through intent in data display design (Crozzoli and Magnusson 2024, 119-121). Extending this point, Reed et al. (2024, 6) argue that aesthetics influence meaning-making via embodied design, which in this experiment takes the form of data exploration. Similarly, Supper (2014, 35) argues how aesthetic strategies can deepen our understanding of data. Building on these insights and Heimann et al. (2023, 3) discussion, we articulate that aesthetic decisions unfold along compositional, sensual, emotional, and spatio-temporal threads of experience (McCarthy and Wright 2004, 79-94) helping to attune

humans into the felt sense though affect. In this experiment, we explore the relevance of such attunement for data display systems, arguing that it enables a finer embodied engagement with the data.

The person engaged in data exploration within this type of system experiences the emergence of meanings in a pre-conceptual state, which they perceive as shifts in their bodily awareness. Embodied processes of knowing then become inscribed in what Kordeš and Demšar (2023, 348) describe as the horizon of attending experience. In this view, horizons delineate how the experience unfolds within the entangled environment shaped by the system's affordances. The felt sense, in turn, is dynamically configured within these horizons, guiding the perceptual dimensions of an ongoing human–data enactment. Consequently, meaning emerges from the interplay between human-experiencing and data, in parallel to Gendlin's (1970, 561) conceptualization that *meaning emerges from the interaction between experiencing and symbols or things.*

Existing interactive systems have worked with embodied cognition and affect, though not always focusing on felt sense. For instance, Sonic Cradle (Vidyarthi and Riecke 2013), an exploratory design using participants breath to investigate meditative attentional pattern, and its follow up project Sonic Cradle - Immersive interaction design combining breathing- and neurofeedback to foster focused attention meditation on breath (Prpa et al. 2016) which integrates live electroencephalogram data from the user to detect the participant focused attention to interact accordingly and create a proper meditation space. Soma Mat (Höök 2018) directs bodily attention with heat following a pre-recorded Feldenkrais lesson, guiding users' awareness toward their bodily states. Wakkary et al. (2018) introduce the tilting bowl as a digital artifact that provokes philosophical co-speculation on human–thing relations, and Liu et al. (2018) adopt a post-anthropocentric perspective to explore human–fungi collaborations, positioning technology as part of a broader ecological relation. Additionally, in line with xCoAx's ongoing dialogue between computation and affect through embodied artistic practice, Hedayati (2023) collects biosignals while viewing emotionally charged footage of protests in Iran. These data are later sonified, expanding an inner experience of trauma into a shared, collective sound-space. While these projects address different aspects of affect, embodied, relational, and more-than-human interactions, they do not explicitly center on the felt sense, nor do they function as design systems for exploratory data analysis.

Dark Sonification is positioned within the discussed context, as a post-interaction technology for designing data displays that conceptu-

alize data as a non-human agent and rewards performativity for embodied cognition through iterative and attentive exploration of the apparatus' relational output. The experiment in this paper makes use of Dark Sonification affordances to explore data perceptualization though affect in the felt sense, and tries to advocate for awareness of the felt sense as a valuable incorporation to data perceptualization though affect.

3. Dark Sonification

Dark Sonification, is an explorative intelligent system designed for uncovering emergent meanings in complex and big data sets through interaction and multimodal display. The project aims to create an accessible data perceptualization system based on machine learning algorithms and deep learning to decode complex structures within big data, and representing these findings through auditory, haptic, and visual feedback. Influenced by the concept that data should be viewed as capta (Drucker 2011, 2-9), this project emphasizes the subjective nature of data, building an ecological human-data environment based on interactive exploration. The project is inspired by data democratization (Lefebvre, Legner, and Fadler 2021, 2-5) aiming for engagement and embodied knowledge as a mode to perceive and understand data.

The architecture of the system involves multiple interconnected intelligent engines: Processing, Mapping, Navigation, and Display. The Processing engine employs libraries like Scikit-Learn for machine learning tasks and PyTorch for building deep learning models, to create a dataset for perceptualization by identifying and decoding structures within big data. The Display engine transforms this processed data into sound, visuals, and haptic feedback, using sound synthesis programming language such as MaxMSP (Puckette 2002) and SuperCollider (McCartney 2002) for sound display, and Tölvera, a powerful Python based ALife library for visualization (Armitage, Shepardson, and Magnusson 2024b, 2-5). The Mapping engine connects the latent spaces generated by the Processing and Display engines, enabling dynamic data representation through customizable mappings between both spaces based on Machine Learning algorithms, such as K-Nearest Neighbours (KNN). The Navigation Engine uses physical controllers, such as gaming and musical instruments, as input for the Mapping Engine, allowing users to navigate Dark Sonification's display.

Dark Sonification is based on a pipeline structure. In its workflow, the human takes analysis, design, and interaction decisions before running visual and sound display engines in parallel (see Fig. 1). The

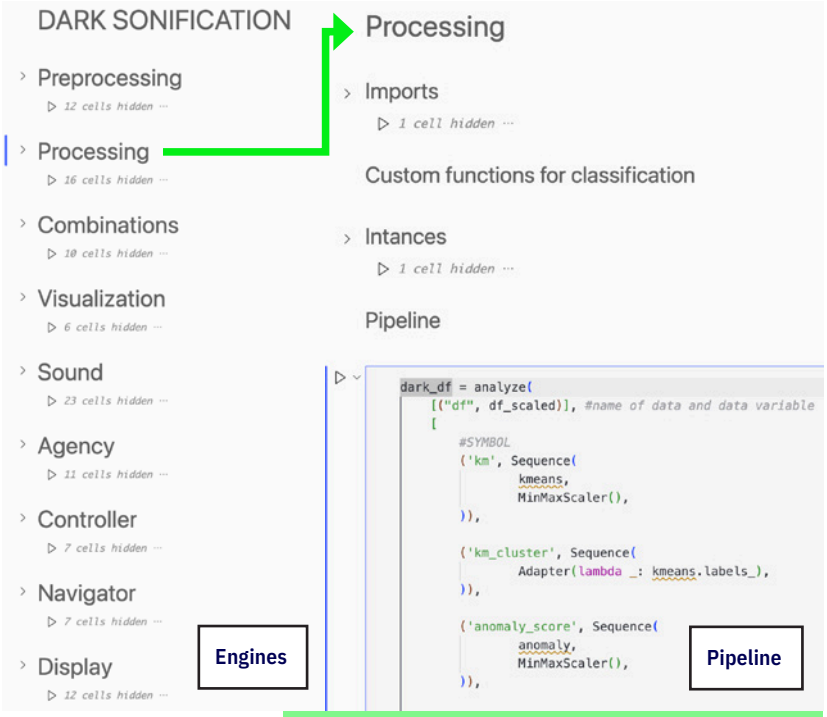

Fig. 1 Dark Sonification Jupiter Notebook structure displaying engines collapsed to the left and Processing pipeline example to the right.

decisions made in the pipeline, will produce a defined range of possible interactive environments. This can be of advantage when strategizing variability for multiple display outputs. These strategies can range from creating detailed customizable mappings where the human decides every aspect of the data translation into display, to mapping data structures through machine learning algorithms and interaction traces with a dense neural networks architecture, where the system self-assigns mappings between engines based on data-human intra-action.

Furthermore, the pipeline can be dynamically modified, allowing the human to change mappings strategies, controllers for navigation, and display types in real time to perceive different structures through different means. Another essential feature is the implementation of interaction traces, which monitor human navigation paths. These traces update maps of attention, influencing macro features of the display such as visual behaviors or more silent spaces for sound corpora navigation. This functionality enables the system to adapt its outputs to reflect the emergent dynamics of the data-human entanglement.

3.1. Affect in the Felt Sense in Dark Sonification

As mentioned previously, one of the main strategies of Dark Sonification is to create a dynamic structure based on human-data intra-action, conceptualized as an environment. In this environment, the embodied controller works as an interface for human-data communication and is this what creates affect in the felt sense. Thus, each interaction allows for the emergence of subsections of this environment as a perceptual field, which is what it is perceived as displayed output. The perceptual field is where affect occurs, and it is defined by its content and shape.

Through interaction, the field properties are continuously updated.

The content of the perceptual field is based on subsections of columns of the data returned by the processing engine. By updating this content through navigation, the space of what can be explored and perceived changes. Interaction also updates the shape of the perceptual field, creating boundaries for the human to experience data within. Each interaction transforms the human perceptual awareness, reinforcing the relational nature of Dark Sonification data exploration. This process is iterative, which is central to Dark Sonification, as it highlights how meaning is co-constituted through continuous human-data interaction.

The perceptual field allows for performative and active engagement which enable humans to perceive data not as an external object but as an extension of their own subjective perception, ultimately becoming one with the data through the perceptual dimension (Petitmengin 2021, 173-174). Based on Petitmengin (2006, 234), here perception occurs within a pre-reflective domain, where bodily awareness precedes conceptualization. Therefore, this experiment focuses on finding shifts in this perception to understand meaning-making processes in a state of pre-conceptual, contextualized in data exploration.

Accordingly, interactivity is situated at the core of this experiment. By making use of gaming controllers to allow interactive and embodied data exploration, we enable an affective co-agency between perception and bodily movement, which Stuart (2015, 103) describes as enkinaesthesia. This co-agency emerges from the entangled experience of actions between objects, being objects human, non-human, or digital (Stuart 2015, 104-105). In Dark Sonification, the act of navigation with the controllers feeds a continuous loop between perception and interaction that become dynamically interrelated within the perceptual dimension of the human, further articulating entanglements between human and data, and both with the system's environment. Based on human-data intra-action in the Dark Sonification workflow, the system crafts an environment that can be thought of as an entangled relational space that allows for interaction. The system's output unfolds based on human-data enactment and system's affordances with dynamic adaptations.

Consequently, by attending to their bodily shifts while interacting with the system, humans access a process that is felt, a pre-reflective mode of embodied knowing through a co-constituted process of relational engagement with data, echoing Schoeller's (2024, 24) reflexive care.

4. Experiment Set Up

The experiment was designed to understand the value of focusing on the felt sense for data exploration in Dark Sonification. Based on Focusing steps (Gendlin, 1978) and Thinking at the Edge movements (Gendlin, 2004), we structured the test into four stages with a set of stage-specific instructions intended to guide participants toward an inward-body awareness. These stages were adapted from Hendricks' (2009, 131) Experiencing Level, which outlines three steps: sensing the felt dimension, recognizing a felt shift, and carrying forward. For this experiment, we added a zero stage to create and guide the participants' awareness to their body to facilitate data-human attunement for the following stages. The four stages are:

- *Stage 0:* Introduction / Clearing a Space: At this initial stage, participants transition from noticing their external surroundings to sensing their bodies through guided breathing exercises. The stage is considered complete once the participants feel aware and connected of their bodily sensation.
- *Stage 1:* Sensing the Felt Dimension: In this stage, participants take the controller and begin exploring data while keeping attention to their bodily sensations. The participant is encouraged to notice the system's sonic and visual feedback through questions like, "How do I sense this data right now?" or "What happens in my body when a particular sound occurs?" The goal is to remain open to how the data feels.
- *Stage 2:* Felt Shift & Handle: Once participants detect a change in their bodily sense (a felt shift), they pause to let the sensation be. They can move away from the data point, then return to it, to notice if the shift persists or evolves. Next, they attempt to form a handle, such as a word, phrase, or image that resonates with the bodily experience.
- *Stage 3:* Carrying Forward: If participants arrive at a word or image that meaningfully aligns with their bodily sense, they pause to acknowledge it, breathing with the felt shift, and let it unfold. At this stage they can take notes, make voice recordings, or save the index of the data point for later conceptualization. Once they articulate the felt shift, they can return to Stage 1 to continue navigating the data or end the exploration.

While stage 0 is meant to be done only once, stages 1, 2, and 3 are repeated in a loop.

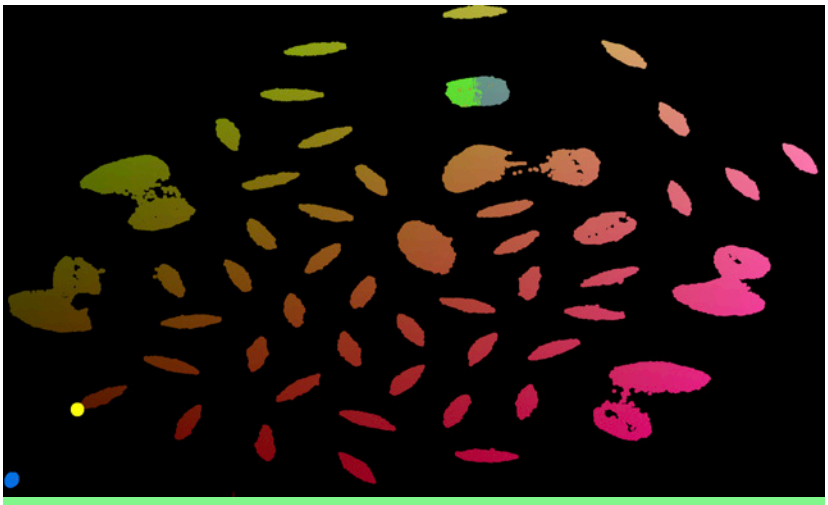

Fig. 2. UMAP dimensions plotted with Tölvera for interactive data exploration

Fig. 3. MaxMSP patch to process incoming data from Dark Sonification with a RAVE model

4.1. Data and System Configuration

We designed a display system based on a controlled toy dataset emulating time series weather data. The dataset consists of 150,000 rows and 10 columns, divided into three clusters, with 10% of the total data points classified as anomalies. In the processing engine, clustering was performed using the K-Means algorithm, and anomalies were detected with Isolation Forest, both imported from SciKit-Learn library. The dataset was also reduced to two dimensions using Uniform Manifold Approximation and Projection (UMAP).

Fig. 4. PlayStation 5 Dual Sense controller used for interactive navigation with the experiment's display

The visual design was constructed as a scatter plot generated with Tölvera, mapping UMAP dimension 0 to the x-axis and dimension 1 to the y-axis. RGB and alpha values were assigned based on cluster id and distance to main cluster for each data point, while anomalies were highlighted using differentiable colors from the clusters (see Fig. 2).

For the sound design, the UMAP dimensions were mapped directly to the latent space of a RAVE (Caillon and Esling 2021, 5-8) model using a KNN algorithm (see Fig. 3). This generated an identity drone sound unique to each data point. These sounds were further pro-

cessed with reverb and delay effects to enhance each cluster's and anomalies' auditory texture and spatial depth. All data used to map the audiovisual display parameters was the data returned from the processing engine.

For data exploration, in the experiment the participants used a PS5 DualSense controller (see Fig. 4), with only the left joystick enabled for navigation to maintain simplicity in interaction. While Dark Sonification supports multimodal feedback, for this study, we focused on audiovisual display, deactivating the system's haptic feedback to minimise cognitive load and keep participants' attention on the inward, felt shifts prompted by the audiovisual pairing.

Overall, the mapping strategy keeps the visual and sonic output synchronized by anchoring them to UMAP components. In this experiment, each x and y position in the plot correspond to a unique latent representation in the RAVE model. Therefore, navigating left-to-right or up-and-down on screen steers the listener through correspondingly unique drone timbres. Additionally, colour saturation encodes each point's distance from its cluster centroid, giving every cluster a recognisable color identity matching spatial latent distribution of our rave model.

4.2. Participants

Four participants were recruited based on diverse criteria, including their prior experience with data displays (as either users or designers), their familiarity with Dark Sonification, and their familiarity with practices addressing directly or indirectly the felt sense, such as focusing or meditation.

4.3. Test Flow

The experiment was conducted with one participant at a time to ensure a controlled and focused environment. Each session took place in an undisturbed setting, with consistent arrangements maintained across all participants. Participants were scheduled on different days to ensure time flexibility if required. At the start of each session, we provided a brief introduction to the technology and the experimental stages, explaining the purpose of this experiment.

The experimental procedure was structured around the designed four stages. Stage 0 was guided by one of us, helping participants to focus on their bodily awareness. In stages 1 to 3, the participants explored the data independently, applying the provided instructions in stage 0 to attune to bodily sensations during exploration (see Fig. 5). If for any reason the participants needed to refocus on their bodily

awareness, they had next to them a printed page with instructions for how to refocus. Participants were given 20 minutes to explore, though they were allowed to end the session earlier if they felt their exploration was complete or felt uncomfortable with the experiment. After completing the exploration, participants were given a pause to process their experience, followed by a semi-structured interview.

Fig. 5. Participants interacting with Dark Sonification for data exploration after stage 0 was completed.

5. Interview

Following the exploration phase in Dark Sonification, each participant took part in a semi-structured interview designed to extract insights from a first-person experiential account. Based on micro-phenomenological techniques (Petitmengin 2006, 239-258), these interviews sought to explore the temporal unfolding of participants' bodily sensations, with a particular focus on identifying felt shift during stages 1 to 3. The methodology involved taking notes, repeating key phrases back to participants, recapping narratives as needed, allowing space for silence, and posing how-oriented, open-ended questions to encourage articulation of subtle changes in the felt sense. All interviews were audio-recorded and later transcribed. First, diachronic description of each session was produced, slicing the transcript into successive experiential units to preserve its temporal flow. Then synchronic comparison across the four narratives was done, looking for recurring markers of felt shift such as tension/release or cross-sensory imagery. Because the coding was handled by a single analyst, the findings remain exploratory yet fit the study's exploratory aim.

Based on the conducted interviews, we can suggest that the use of Dark Sonification together with the designed stages and their instructions, facilitated an embodied awareness for interactive data exploration. Participants described their experiences through rich bodily descriptions, imagery, and metaphors, generally comparing the experience to a meditation practice.

A recurring theme was encountering zones of "tension and release" in the data display. Participant 1 noted, "I started to look for sounds that would release some of this tension...I would find the spots that were opening up and (deep breath) now I can breathe out again and reconnect." Similarly, participant 2 characterized his experience as "a constant game between tension and release while I was searching." and Participant 4 noted how some areas made her feel "heavy in the lower back," whereas others "light and airy." Both Participants 1 and 2 referred to certain data points as "safe zones." These observations

Fig. 5. Participants interacting with Dark Sonification for data exploration after stage 0 was completed.

confirm the participants' body awareness and the affect of the display in their bodily state.

Another outcome was the cross-sensory associations participants reported, particularly with smell. Participant 1 recalled detecting "palo santo," even though there were no odors in the experiment room, while Participant 2 perceived "changing smells...metal, maybe the room, air-conditioned smell," despite the system having no olfactory output. These observations align with Petitmengin et al. (2009, 282-283) notion of transposability across senses, indicating that hearing and/or seeing was transposed to olfactory sensations, suggesting a fine data-body attunement.

Participants also articulated metaphors and mental imagery tied to specific sonic or visual clusters. Participant 3 described perceiving data points as "spiraling downwards" or "flying through space," while participant 4 referred to "a sense of aura." These descriptions correspond to multimodality in the felt sense, which Petitmengin et al. (2009, 277) articulate in the felt sound.

Some participants also noticed memories linked to places tied to specific points of exploration or transitions between points. Participant 1, for instance, mentioned memories of pine trees near an Italian seashore. This recollection can potentially unfold contextual meaning-making of the data point if the participant unfolds the experience.

Moreover, two participants mentioned focusing on their heartbeat while navigating. Participant 4 stated, "When you think about it, you're like, 'Oh, there's my heart,' and it kinda pulls you down to Earth. I felt it more in those in-between moments moving around the display, not really sure what I'd find. But noticing it now actually centers me." This illustrates a synchronization of inner and outer space while experiencing in the felt sense, paralleling Petitmengin et al. (2009, 273) regarding experiential space of the felt sound.

More abstract and increasingly interesting reflections also emerged during the interview about how this approach could be used. Participant 1 compared the experience to "a ritualistic scenario...where you need to prepare in order to be welcomed," in line with more-than-human ethics proposed by post-human studies. Participant 4 speculated on applying this experiment to mundane spreadsheet tasks, emphasizing, "I think it could give me a lot...acknowledging everything around you has a lot of impact." Such comments highlight the participants' curiosity about integrating embodied techniques into different scenarios of data handling, thereby expanding conventional definitions of data literacy and entering in the terrain of data ethics.

Overall, during the interviews, descriptions from the participants diverged from traditional data-analytic language. Instead, participants framed their insights via bodily shifts and sensory impressions, consistent with the pre-conceptual articulation that the experiment sought after.

6. Limitations

Despite these rich observations, there are limitations to the experiment. First, even with the diverse background and expertise of the participants, the sample size for the study falls short, limiting generalization of our findings. Second, focusing on the felt sense might be difficult in a real-world scenario, and domain-specific knowledge could also create a barrier to allow a more ludic approach to data exploration, putting in doubt the applicability of such techniques for data exploration. Third, one participant struggled with wearing headphones at the beginning, which required re-focusing on their bodily sense. Offering more training time or different interfaces based on participants' capacities needs to be implemented to mitigate circumstances. Additionally, this paper theorises and exemplifies the value of working with the felt sense in data-display systems rather than an exhaustive study of parameter-mapping strategies for designers to work with the felt sense. We identify this as a potential study, applying the structural analysis of listening to the felt-sound proposed by Petitmengin et al. (2009) to concrete mapping scenarios.

7. Conclusion

After conducting this experiment, we can suggest that focusing on the felt sense for data perceptualization through affect is a valuable complementary method to traditional approaches in exploratory data analysis. By engaging participants in embodied awareness for data exploration, our study showed a pre-conceptual dimension of meaning-making; rich in sensory experiences that describe a structural and personal perception of the data. The results offer insights into a reflective layer of data exploration articulated through sensory language, in contrast to the technical language typically used in conventional exploratory data analysis.

Different fields can make use of this sensory experience based on intent in their data exploration project. While it can be easily adapted in the context of information dissemination and artistic expression, scientific data exploration contexts might require a more refined understanding of its usability. A straightforward implementation is to begin each data exploration with clearing-the-space, as explained in stage 0 in Section 4, allowing users to attune to their embodied awareness before the system activates. Moreover, using pencil and

paper to take notes, or allowing the system to save data indices and record voice memos can help users to capture when the felt-shift occurs. These notes and logs can later be revisited alongside conventional analytics, turning subjective insight into a traceable design asset. Nevertheless, we suggest that further studies are needed to compare insights derived from the felt-sense in data exploration with those from traditional methods, using a control toy data set as a benchmark. In our view these studies are not meant for accuracy, but to understand which other complementary data insights we can find through focusing on the felt sense. Interestingly, our participants expressed a strong interest in tools that facilitate human-data engagement by focusing on the felt sense. Future studies should also explore how embodied techniques, such as focusing and thinking at the edge, can be integrated with other data analysis methods.

Ultimately, this study encourages the investigation and inclusion of diverse embodied ways of knowing to create more and different modes of accessing data. In times of global polycrisis, where major decisions are driven and controlled by data insights, expanding strategies of interaction and perception is a necessary act for community empowerment.

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