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VibViz: Organizing, visualizing and navigating vibration libraries*

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***Abstract*— With haptics now common in consumer devices, diversity in tactile perception and aesthetic preferences confound haptic designers. End-user customization out of example sets is an obvious solution, but haptic collections are notoriously difficult to explore. This work addresses the provision of easy and highly navigable access to large, diverse sets of vibrotactile stimuli, on the premise that multiple access pathways facilitate discovery and engagement. We propose and examine five disparate organization schemes (taxonomies), describe how we created a 120-item library with diverse functional and affective characteristics, and present *VibViz*, an interactive tool for end-user library navigation and our own investigation of how different taxonomies can assist navigation. An exploratory user study with and of *VibViz* suggests that most users gravitate towards an organization based on sensory and emotional terms, but also exposes rich variations in their navigation patterns and insights into the basis of effective haptic library navigation.**

I. INTRODUCTION

Vibrotactile (VT) technology appeared in mainstream consumer culture over a decade ago, first in buzzing cell phones and game controllers. However, despite improvement in quality and expressiveness of consumer-grade tactile display, user appreciation and adoption has remained low.

One culprit is slow growth in the value added by haptics, e.g., "informative" uses wherein different stimuli have different assigned meanings [7], [11]. Low utility interacts closely with low liking: whether a user finds a tool hard to use or just dislikes it, he responds to the consequent irritations, learning difficulty and incomprehensibility by minimizing or disabling it. The high incidence of online user posts for haptic features asking how to "turn it off" suggests one or both of these are in fact happening with haptics.

Individual differences in haptic perception and preferences may be at the root of this problem. Underscoring this premise is the emerging theme of a need to recognize user diversity in end-user haptics research [17], [15], [9], [3], [4]. Would "turn-it-off" individuals see more value in tactile feedback if it met their *own* specifications?

Diverse example sets, or libraries, are an obvious way to assist a user with customization [9], [15]; but now we face the *navigation* challenge. Unlike visual images, vibrations must be scanned serially with most displays. Feeling and finding the entire contents of a sizable library is tedious and physiologically infeasible, as the first few vibrations quickly numb tactile receptors. A user may want to compare or choose multiple stimuli for their applications, but comparing

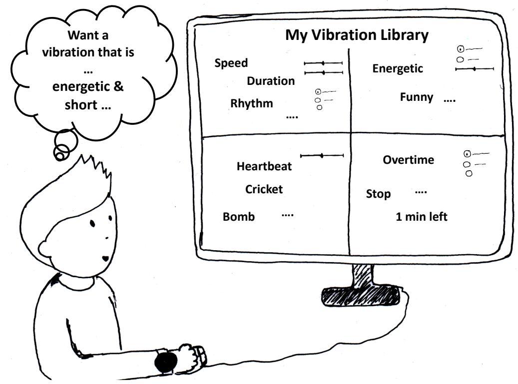

Fig. 1: Users need an intuitive interface for navigating a VT library.

and selecting from a rich multidimensional set is daunting. Confused and exhausted, users soon give up.

We are inspired by approaches taken in other domains to achieve highly navigable access to large, diverse collections. This includes principles such as offering multiple organizational schemes, informative and distinct visual representations, highlighting adjacencies between items and engaging users. While some publicly available VT libraries exist, the accessibility of this valuable resource is obstructed by the general absence of these elements.

Approach: The present research explores *how organization and representation of a VT collection can best support users in finding their desired vibrations.* Specifically, we identified five potential ways ("taxonomies") for organizing effects. We created a library of 120 vibrations (for a single actuator), large enough to pose significant navigational needs, annotated it by taxonomy, and created *VibViz*, an interactive visualization interface with the goals of supporting both end-user navigation and our investigation of our five taxonomies' utility and engaging qualities. Finally, we conducted a preliminary evaluation of *VibViz* and the five taxonomies using our VT library, in a user study with 12 participants where we triangulated questionnaire and observation data. Our contributions include:

- a process for creating a large (120 items) VT library
- identified challenges for large tactile library design
- five potential organization schemes (taxonomies) for VT effects, drawn from literature
- an interactive library navigation interface (*VibViz*)
- a first evaluation of *VibViz* and the five taxonomies

II. RELATED WORK

A. VT Libraries

Some large collections of VT effects exist, including Haptic Effects preview and Haptic Muse by Immersion (124 vibra-

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tions) [3], [4], and FeelEffects by Disney Research (>50 vibrations for a haptic seat pad) [9]. Each uses a single organizing principle: FeelEffects are grouped into 6 types of sensations or metaphors (e.g., rain, travel, motor sounds) and Haptic Muse by gaming use cases (sports, casino).

Other examples organize items on multiple dimensions simultaneously, but these axes occupy the same domain; e.g., van Erp (59 VT melodies) [20] and Ternes & MacLean (84 items varying on note length, rhythm, frequency, and amplitude) [18]. Relevantly, Ternes used MDS to translate a purely physical design space into perceptual dimensions [18], to facilitate "spacing out" its elements for maximum perceptual diversity given a device's capabilities.

Here we further hypothesize that restructuring a library over different *domains* will not only help optimize perceptual item packing for a given hardware's expressive capability, but also make it more accessible via multiple, qualitatively different means of exploring and understanding it.

B. VT Taxonomies

VT effects can vary in many ways. Most examined are physical characteristics, including intensity, duration, temporal onset, rhythm structure, rhythm evenness, note length, and location [10], all measurable from the vibration signal. Research on tactile language suggests that users often describe vibrations with sensory and emotional words [20], [13], [14], motivating Guest et al's sensory and emotional dictionary for tactile sensations [8]. Schneider & MacLean found that people use familiar examples or metaphors (e.g., whistle, cat pawing) for describing vibrations [14]. Vibrations may also be characterized by their usage context (e.g., double click vibrations [3]) and example (cellphone vibrations).

We synthesized the above literature into five initial taxonomies for VT effects, intended for structuring and accessing a large VT collection: 1) *Physical* characteristics – e.g., duration, energy ("1 second long"), 2) *Sensory* characteristics – e.g., roughness ("feels rough or changing"), 3) *Emotional* characteristics – e.g., pleasantness, arousal, and other emotion words ("feels urgent"), 4) *Usage Examples* – types of events for which a stimulus could be used ("good for a reminder"), and 5) *Metaphors* – familiar examples that resemble the effect in some way ("feels like snoring").

C. Inspiration from Visualization and Media Collections

Research on books and other media suggests that multiple visual pathways to a library can promote exploration and engagement, and increase serendipitous discovery [19]. Musicovery, an online music streaming service, visualizes its collection based on music mood and emotional content and allows filtering by genre, date, artist and activity [5]. However, unlike books and music, the most relevant alternative taxonomies for VT stimuli have not been clearly identified.

Our library interface borrows many guidelines from the information visualization (InfoVis) domain, including using multiple views and linking their content. In InfoVis terminology, "filtering" refers to reducing the number of elements shown on the screen to a smaller subset of interest and a "glyph" can refer to any complex visual item, in contrast to single geometric primitives such as dots and squares [12].

III. LIBRARY & TAXONOMY CONSTRUCTION

Our library includes 120 vibrations, a size chosen to require an effective organization scheme. Elements range from 0.1s to 14.6s in duration and 0.05 to 0.734 in energy (signal RMS). In the present study, stimuli are rendered by a C2 actuator [2]. In the following, we describe how we designed the library and specified our five taxonomies, and discuss obstacles we encountered.

A. Library Population

Our library required significant and diverse representation across all of our eventual taxonomies to the extent possible given available physical parameters. We "sourced" effects through a variety of methods, including:

- collected a repository of effects from our past studies and collaborations with industry,
- systematically generated a large set of vibrations by varying the rhythm, frequency, and envelope structure,
- asked our haptics colleagues to design vibrations for a given list of metaphors (e.g., a dog, a spring, panting) with a rapid prototyping tool called mHive [14],
- constructed vibrations based on the Apple iPhone's sound icons, either mimicking timing and frequency changes, or directly applying low-pass filtering to them.
- for all of above, iteratively generated variants on existing vibrations and pruned overly-similar instances.

To balance taxonomic representation, at several points we annotated its contents according to the current description of our taxonomies. This in turn led us to refine our taxonomic descriptions, with the final result in Table I.

B. Visualizing and Managing Diversity During Growth

As the library grew, it became harder to assess progress towards a goal of evenly distributed diversity; to compare ex-

TABLE I: Final VT Taxonomies used in study.

1. Physical: Properties of a vibration that can be measured. 1) *duration* (msec), 2) *energy* (RMS), 3) *tempo* or speed (annotator-rated), 4) *rhythm structure*. For (4), we categorized stimuli by rhythm following [18]: a) *short note:* all pulses <0.25s b) *medium note:* all pulses 0.25s<0.75s c) *long note:* all pulses >0.75s d) *varied note:* combination of short, medium, and long pulses e) *constant:* single pulse
2. Sensory: Vibration perceptual properties. 1) *roughness,* 2) *sensory words* from touch dictionary [8].
3. Emotional: Emotional interpretations of vibration. 1) *pleasantness*, 2) *arousal*, 3) dictionary *emotion words* [8].
4. Usage Examples: Types of events which a vibration fits. We collected and consolidated a set of usage examples for presentation timing and exercise tracking (Tam et al. [17]).
5. Metaphor: Familiar examples resembling the vibration's feel. With a questionnaire, we collected a set of metaphors for our list of usage examples, asked colleagues and friends to provide metaphors for our VT effects, and used the NounProject website [6] for brainstorming on metaphors.

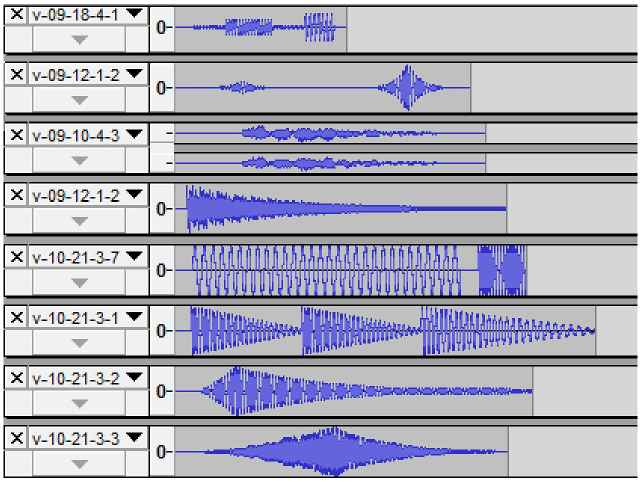


Fig. 2: Using Audacity for visual comparison of vibrations

isting effects, prune similar ones and find gaps. We responded with several organizing and visualization mechanisms.

1) We built a database of existing vibrations in a spreadsheet; each row represented one vibration. Columns indicated vibration properties for each taxonomy, and could be filtered. Despite addressing our most immediate needs, this approach had several drawbacks including limited filtering functionality, slow vibration playback, lack of a visual representation for the vibration patterns to support quick visual scanning.

2) To improve visual inspection, we stacked subsets (about 30) of vibration waveforms in Audacity, a sound authoring tool, for quick VT modification and playback [1](Figure 2). The improved visualization qualities eased identification of near-duplicates and omitted vibration structures.

3) Finally, we plotted vibrations according to their emotional (pleasantness and arousal) and physical characteristics (energy, duration, tempo, etc.) to enable successive pruning and filling along each dimension.

These mechanisms eventually conveyed us to an adequate result, but were cumbersome; worse, their fragmented nature hindered iteration, sometimes guiding modifications in conflicting directions. However, the experience of building this library gave us direct insight into the situation faced by any user in navigating a large, unstructured and poorly visualized set of items. The specific problem of navigation emerged as a primary obstacle to its use, whether for customization or any other kind of design, and inspired us to turn to other interactive visualization mediums to craft a better solution.

IV. VIBVIZ: AN INTERACTVE LIBRARY NAVIGATION TOOL

A. Requirements

We needed our library interface to do two jobs, in the context of customization tasks: 1) support novice end-users in vibration discovery (for example, in an online or local vibration library); and 2) allow us to study the utility and appeal of our five VT taxonomies.

To support end-users, the interface must be easy to use without training. It needs to support both search and exploration; we anticipate that sometimes users will want to search with a set of characteristics in mind, and other times explore with minimal direction. It must support discovery of vibrations that resemble or contrast to a reference. It should provide multiple pathways, a key to serendipitous discoveries; and its use should be engaging enough to invite curiosity-driven exploration [19]. As a research tool, the interface needed to provide clear taxonomical separation, allowing us to study user interactions by taxonomy and users to articulate their opinions.

B. VibViz Interface

Designed based on these requirements, *VibViz* is an interactive visualization with three views (Physical, Sensory/Emotional and Metaphor/Usage Example – Table II), each with a screen area containing vibration representations and filter controls (Figure 3a). Several features bear notice:

Linked views- All views show the same vibration subset at any time: a filter applied to one controls the others, and hovering over a vibration in one highlights that vibration elsewhere. Hovering over a tag in the tagclouds highlights associated vibrations in all three views.

Thumbnail design- A vibration glyph automatically highlights central characteristics of each vibration waveform and renders it as a thumbnail. The glyph encodes vibration frequency with colour saturation and a darker stroke envelope to highlight vibration pattern over time.

Drill-down and marking- A left or right click on a vibration respectively opens a detail popup (Figure 3b), or bookmarks it. Marked vibrations have a highlighted border.

VibViz is best displayed on screen sizes equal to or larger than 12 inch and is designed for a single actuator. For multiple actuators, the user can playback one vibration simultaneously on several actuators or rely on the application program (e.g., exercise tracking application).

C. Dataset

To use our VT library in *VibViz*, each vibration had to be annotated for all five taxonomies. We measured vibration duration, energy, and pulse structure. Three researchers rated and annotated the other vibration properties; one annotated all and two half of the library. We averaged ratings and removed any pairs of contradicting tags.

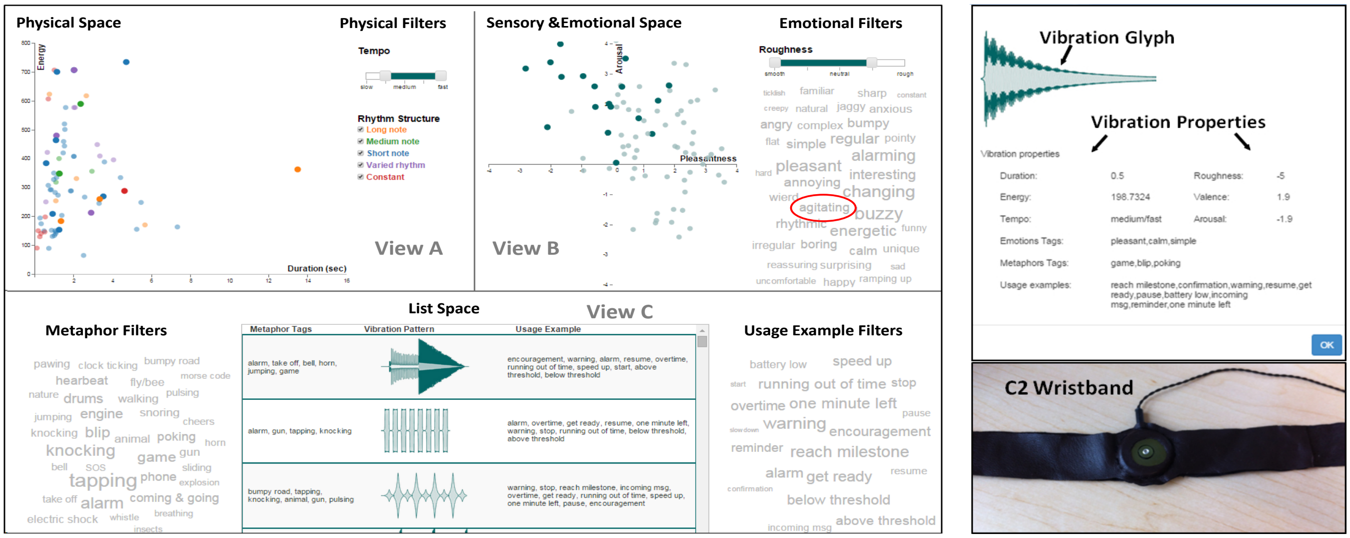
V. USER STUDY

We ran a small user study to investigate two questions:

RQ1) Does *VibViz satisfy its design requirements?* (Research tool; supports novice use, search, exploration, finding similar/contrasting items, serendipity, multiple pathways).

RQ2) How *useful* is each taxonomy for customization? How *interesting* is each for end-users? As pathways to exploring the library, does their *multiplicity* provide significant utility and interest over a single view?

Participants and Procedure- We recruited 12 participants (7 female) using flyers and social media posts, for a 1-hour study and $10. The majority (8 out of 12) of the participants did not have any prior VT background beyond their cellphone vibration notifications. Three participants had attended VT demos or user studies in the past and one had experience in



(a) *VibViz* interface- Hovering over a tag in any of the tagclouds (here, the agitating tag, circled in red, highlights the associated vibrations on all three views. This is done with: more saturated colors in view A, B and with a dark frame in view C. The labels " View A, B, C" are included for explanation and were not visible to participants.

(b) Detailed vibration popup in *VibViz* (top) and C2 wristband (bottom)

Fig. 3: The *VibViz* interface and C2 wristband that renders the vibrations

TABLE II: *VibViz* user interface view descriptions.

General Characteristics: - Views A, B and C occupy the upper left, upper right and lower regions of the interface screen, respectively (Figure 3a). - We combined *Sensory* and *Emotional* taxonomies due to tag overlap (View B). *Metaphor* and *Usage Example* taxonomies share the vibration glyph on View C to save screen space. - Hovering over a dot (Views A-B) or row (View C) shows a visual thumbnail of the vibration pattern (glyph) and plays the vibration on the tactile display.
A. Physical View: Provides an overview of all the vibrations, each represented by a coloured dot, according to axes of *energy* (vertical) and *duration* (horizontal). *Filters:* 1) *Tempo* – slider for speed. 2) *Pulse structure* – checkboxes, with colours matching associated dots, for *short note*, *medium note*, etc. 3) *Horizontal zooming* – click & drag on the Physical space zooms on the horizontal *duration* axis.
B. Sensory and Emotional View: Each vibration appears as a dot in a 2D arousal–pleasantness space. *Filters:* 1) *Roughness* slider and 2) *Sensory and Emotion words* tagcloud. Changing the roughness range or clicking on the tagcloud selects vibrations having a roughness level in the specified range, and all of the currently selected tags.
C. Metaphor and Usage Example View: A central, scrollable list of vibrations is flanked by *Metaphor* and *Usage Example* tagclouds. Each row has three columns: the vibration's *Metaphor* tags, its glyph, and its *Usage Examples*. *Filters:* Clicking on tags in either tagcloud reduces the displayed list to vibrations that have the specified tag(s).

designing vibration patterns. We audio-recorded sessions and asked participants to verbalize their thoughts throughout.

In a pre-questionnaire, participants wrote down 1-2 daily activities and their preferred notifications (e.g., activity: running; notification: start and end of each interval). They then explored *VibViz* (displayed on a 14 inch laptop screen) for 10 minutes to get a sense of its features, while wearing a C2 tactor held in a wristband (Figure 3a-c); the experimenter answered any questions about the interface. Participants next completed 9 scenarios (one at a time, 4 warm-up and 5 complex – Table III), with random ordering in each set ($\leq$ 3 min per scenario). Warm-up scenarios were clearly linked to one taxonomy; complex scenarios were open-ended but common tasks in customizing real world VT notifications and thus, were subject to interpretation. For example, the like/dislike scenarios were included to mimic situations where users' knowledge of the desired VT notification is purely implicit and visceral. Finally, participants filled a post-questionnaire. Throughout the session, the experimenter sat beside the participant and used an observation sheet to record confusions, comments and actions taken to complete each scenario.

TABLE III: Study scenarios. Green/warm-up; blue/complex.

Scenario	Description
Sc (Physical)	Find a vibration that is "short" in duration, "strong", and "fast".
Sc (Emotional)	Find a vibration that is "urgent" and "pleasant".
Sc (Metaphor)	Find a vibration that feels like a "fly or bee".
Sc (Usage Example)	Find a vibration that is good for both "start" and "stop" notifications.
Sc (Like)	Find a vibration that you like.
Sc (Not like)	Find a vibration that you do not like.
Sc (Pre-Q)	Find a vibration for the notification you wrote on the pre-questionnaire.
Sc (Combined)	Find a vibration that feels "natural", catches your attention, and is good for "every 5 minute notification".
Sc (Similar)	Find a vibration similar to the last vibration you chose.

Data and Analysis- Our data consisted of demographics and notification types from pre-questionnaire, the experimenter's notes on confusions and list of actions for each scenario, and ratings and comments from the post-questionnaire.

During the study, we noticed that sometimes participants used the *List*, *Physical*, or *Sensory/Emotional* spaces to explore the vibrations without using the characteristics of that taxonomy. Thus, we analyzed participants' actions on filters and spaces separately. Due to the study's small size and interesting variations among participants, we rely on summary statistics such as counts and percentages instead of statistical tests.

VI. RESULTS

We structure this section according to our research questions.

A. RQ1) Does VibViz satisfy our design requirements?

1- Serve as a research tool for VT researchers: *VibViz* provided adequate separation to allow us to observe and log participants' actions by taxonomy. With the current design, however, one would need a combination of software logging and eye-tracking to automatically collect meaningful data.

2- Support novice users: Participant comments indicated that several terms and controls were confusing during initial exploration: *Rhythm structure* (10 participants), *Arousal* dimension (5), *AND/OR* filter operation (4). Also, none of the participants discovered the ability to bookmark vibrations or perform a physical zoom until they were told. 4 and 3 people respectively did not notice linked filtering or linked highlighting of vibrations across all views.

3- Support end-users in search and exploration tasks: According to post-questionnaire data, 9 participants followed "an explicit search" and 9 "a less-focused exploration" strategy, "many times" or "always", to find the vibrations. E.g., P1 stated that *"finding vibrations always started with an explicit search up to the point that I filtered everything that I thought might not be the proper ones for the scenario. Then I explored among the available filtered options"*.

4- Support users in finding similar vibrations: 6 participants used the visual VT glyphs and *List* space, 4 used proximity on the *Sensory/Emotional* space and 2 used *Metaphor* or *Usage Example* tags to find similar vibrations.

5- Facilitate serendipitous discoveries: Based on the definition of serendipity in [19], the frequency of finding a vibration "by accident" or "by a less-focused exploration" can be a measure of serendipitous discoveries. 8 participants found an interesting vibration "by accident", 9 found the scenario vibrations "by accident", and 11 found them "by a less-focused exploration" for at least "a few times".

6- Provide multiple pathways to the VT library: Based on the percentage of actions (Figure 4), 7 participants used elements of at least two separate taxonomies in more than 20% of actions. Participants also varied in their preferred filter and space combinations; e.g., P4 never used the *List* space, while P9 used it frequently (62%). All participants used different pathways for different tasks (Figure 5).

B. RQ2) How useful and interesting is each VT taxonomy?

Taxonomy interest and utility- According to post-questionnaire data (Figure 6), participants found the combination of all views most interesting, followed by *Sensory/Emotional*. *Physical* and *Usage Example* were least interesting. Similarly, all the views were perceived as useful, led by the full combination and *Sensory/Emotional*.

	Filters				Spaces		
	Physical	Emotional	Metaphor	Usage Example	Physical	Emotional	List
P1	0.24	0.16	0.13	0.04	0.16	0.05	0.23
P2	0.11	0.26	0.07	0.19	0.06	0.27	0.06
P3	0.09	0.22	0.06	0.07	0	0	0.56
P4	0.19	0.23	0.09	0.12	0.09	0.28	0
P5	0.19	0.26	0.07	0.22	0.12	0.1	0.04
P6	0.16	0.26	0.11	0.07	0.04	0.21	0.14
P7	0.19	0.02	0.27	0.06	0.06	0	0.38
P8	0.17	0.25	0.09	0.03	0.08	0.1	0.27
P9	0.11	0.11	0.06	0	0.02	0.1	0.62
P10	0.11	0.32	0	0	0.13	0.3	0.13
P11	0.04	0.27	0.11	0.07	0.22	0.13	0.15
P12	0.23	0.32	0.13	0.02	0.06	0.15	0.09

Fig. 4: Average filter and space usage per participant

	Filters				Spaces		
All users	Physical	Emotional	Metaphor	Usage Example	Physical	Emotional	List
Sc(Physical)	0.57	0.09	0.02	0.02	0.21	0.07	0.04
Sc(Emotional)	0.17	0.41	0.02	0.08	0.04	0.22	0.07
Sc(Metaphor)	0.05	0.13	0.38	0	0.08	0.09	0.26
Sc(Usage Example)	0.1	0.16	0.07	0.33	0.08	0.13	0.14
Sc(Like)	0.05	0.35	0.06	0.02	0.03	0.2	0.3
Sc(Not Like)	0.05	0.3	0.02	0.05	0.03	0.23	0.33
Sc(Pre-Q)	0.19	0.13	0.08	0.07	0.18	0.05	0.3
Sc(Combined)	0.07	0.32	0.1	0.08	0.11	0.14	0.16
Sc(Similar)	0.12	0.13	0.14	0.03	0.03	0.15	0.39

Fig. 5: Average filter and space usage per scenario

Frequency of taxonomy use- In response to the question "Which of the following views would you use most often?", 8/12 participants chose *Sensory/Emotional*, 3 of whom wanted it in combination with the *Metaphor* or *Physical* views. According to P6, *"they are all useful for different things...I think I can use the Metaphor and Emotional view most of the time and occasionally switch to the other ones for a specific task"*. P8 had a similar comment. Among others, 3 selected the *Usage Example* and 1 the *Physical* view. Our observation data generally aligned with post-questionnaire data. On average, *Sensory/Emotional* filters were used most (22%), followed by *Physical*(15%), *Metaphor*(9%) and *Usage Example* filters(8%).

Mismatches- Post-questionnaire responses from P2, P7, and P9 conflicted with our observations. P2 chose *Usage Example* on the post-questionnaire but used *Sensory/Emotional* most often (26%). This difference was likely due to her stated dislike for the tagcloud design for the *Usage Example* filters. P9 chose *Sensory/Emotional* but mostly used the *List*

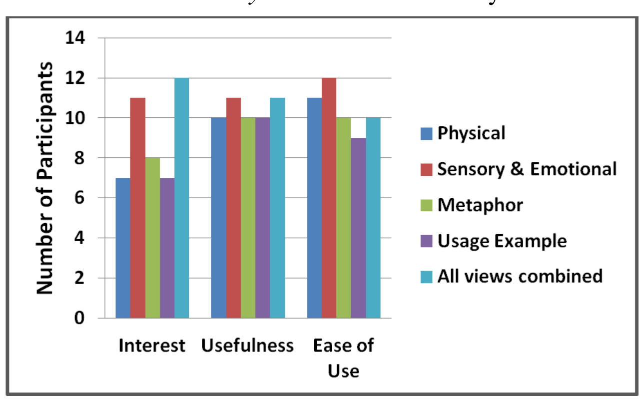


Fig. 6: Interest, usefulness, and ease of use for the VT taxonomies based on the post-questionnaire data

space (62%) during the scenarios, noting that *"I want to go through them all, don't wanna miss some by filtering."* Most curiously, P7 chose *Usage Example* but used it the least during the study. We cannot speculate on the reason. We did not notice any differences in the usage patterns of the four participants who had attended VT demos or user studies or had VT design experience.

Other useful features- Visual VT glyphs were appreciated (9/12 rated them as somewhat or very useful). In our observation, they were especially helpful for finding a previously seen/felt vibration, and for finding similar vibrations. According to P4, *"Based on the visual pattern, I started to realize which ones I like and don't like."* The *List* space was also used frequently (22%) for going through all the remaining vibrations. Also, P3, and P9 mainly used the *List* space for the complex scenarios since they felt that their perception of vibrations did not match some of the tags.

VII. DISCUSSION

A. Interface requirements

Our study results suggest **several features that are important for a VT library navigation:** 1) filtering functionality, 2) visual vibration pattern, 3) spatial and tabular presentations, 4) bookmarking, and 5) simple VT authoring tools.

We found that filters supported the search task and helped users narrow down to a VT subset that matched their criteria, while the visual vibration glyphs, list (tabular), and spatial representations were most useful for exploration. The spatial and tabular representations allowed the users to flexibly sample the library, but the visual vibration glyphs made this exploration quicker and also assisted in similarity search. In some cases, participants wanted to adjust the sensation of a vibration; this calls for **incorporating simple authoring tools** into VT library navigation interfaces [16].

B. VT taxonomies

Keep all, show a subset, allow switching- Although the majority of users found a combination of taxonomies most interesting and useful and used all the taxonomies at some point, most often each only used about two views. Thus, we think the library navigation interface could show a subset of views to the users but allow them to switch to other views as needed. Reducing the number of views frees up screen space for other useful functionality (e.g., a personal view for a favorite vibration subset or for temporary comparison) and makes the tool viable for smaller screen sizes.

Support personalization- Users appear to vary in which subset of the views they prefer. Thus, supporting personalization of default views is an important requirement. If only a single taxonomy can be incorporated, our results suggest that the *Sensory/Emotional* view is a reasonable default.

VIII. CONCLUSIONS AND FUTURE WORK

We developed and studied five organization and navigation schemes (VT taxonomies) for a library of 120 vibrations. We designed *VibViz*, an interactive library navigation tool, to: 1) support novice end-users in customizing VT notifications, and 2) serve us as a research tool for studying the utility and appeal of the taxonomies. Our user study with 12 participants found greatest interest in the *Sensory/Emotional* taxonomy, but also interesting variations among participants in preference for all the taxonomies. Our results revealed the importance of visual scanning (tabular and spatial overview, and visual VT pattern) for efficient library navigation.

Our next step is to collect library annotations from a large group of users and study variations in their ratings and usage, and extend *VibViz* to support additional customization tasks, such as vibration set creation and item comparisons. In the long term, we plan to conduct a field study on end-user customization of VT applications using our library and an improved *VibViz* interface.

ACKNOWLEDGMENT

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