

Studying Design Process and Example Use with Macaron, a Web-based Vibrotactile Effect Editor

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Abstract—Examples are a critical part of any design process, but supporting their use for a haptic medium is nontrivial. Current libraries for vibrotactile (VT) effects provide neither insight into examples’ construction nor capability for deconstruction and re-composition. To investigate the special requirements of example use for VT design, we studied designers as they used a web-based effect editor, *Macaron*, which we created as both an evaluation platform and a practical tool. We qualitatively characterized participants’ design processes and observed two basic example uses: as a starting point or template for a design task, and as a learning method. We discuss how features supporting internal visibility and composition influenced these example uses, and articulate several implications for VT editing tools and libraries of VT examples. We conclude with future work, including plans to deploy *Macaron* online to examine examples and other aspects of VT design *in situ*.

I. INTRODUCTION

Creativity often sparks when an inventor, examining existing ideas, sees a way to combine them with a novel twist [1]. An environment rich with *examples* is fuel for this fire. In industrial and graphic design [2], [3] their use improves process and final results [4], [5].

Several effect libraries are available to designers of vibrotactile (VT) sensations, e.g., for accessible wayfinding [6] or media experiences [7]–[10]. But despite the need for effect customizability [11], VT library elements are generally opaque in construction and immutable. Recent advances include limited parameter adjustability [7], [8] and faceted library search and browsing [12]. Despite this, designers still must either choose a pre-existing sensation or build from scratch: *elements cannot be sampled, recombined, built upon or adapted*. In contrast, web designers can access a page’s source; graphic and sound designers can sample and incorporate colours and sounds from other media.

Here, we *examine the potential role of examples* in VT design, to establish how to best support their use. We designed a web-based editor and interactive *design gallery* [5], [13] (Figure 1) for VT sensations, then asked users to compare versions (Figure 2) that vary in example accessibility via *visibility* and *incorporability*, as they create VT effects for animations (Figure 3).

Analysis of user action logs provide an objective picture of the VT design process. To validate the deployment of this methodology at scale, we also interpret and validate logs with direct observation and interviews. Specifically, we:

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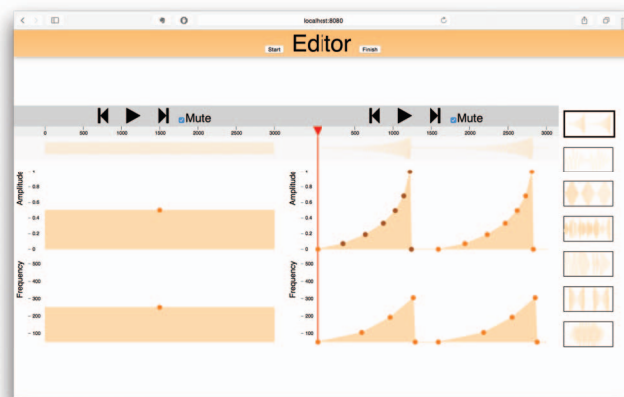


Fig. 1: Macaron interface, “hi” version featuring both composability (copy and paste), and visibility of underlying parameters. The user edits her sensation on the left, while examples are selected and shown on the right. One editor has focus at a time, shown by the red playhead. Examples are non-modifiable (keyframes cannot be inserted or moved). Macaron is publicly available at hapticdesign.github.io/macaron.

- introduce *Macaron*, a web-based VT effect editor through which examples can be used directly in designs,
- find that *visible, incorporable examples make design easier* by providing a starting point for design and scaffolding to learn how to work with VT parameters,
- identify *implications for future tools and libraries*, and
- discuss the *opportunities afforded by a web-based editor* as a practical tool and platform for studying other aspects of VT design at scale.

II. RELATED WORK

A. Salient factors in VT effect perception and control

Vibrotactile effects (e.g. haptic icons [14]) are typically manipulated with low-level engineering of signal parameters, beginning with amplitude, frequency and waveform [14]–[17]. Rhythm can support large, learnable icon sets [18], [19]; combining waveforms enhances roughness [20]. Time-varying amplitude adds musical expressivity, from tactile crescendos [21] to envelopes [22]. Multi-dimensional scaling can be used to identify and elaborate these parameters [14], [23]–[25].

Affect and metaphor are another way to structure and manipulate sensations at a level more cognitively relevant than engineering parameters. Perceived valence (pleasantness) and

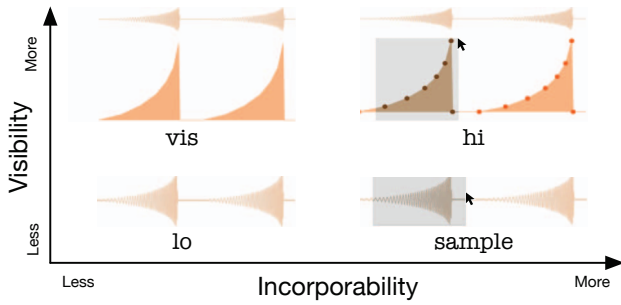


Fig. 2: Design space for Macaron versions. *hi* and *sample* both allow for selection and copying of example keyframes. *vis* and *hi* both show the underlying profiles. *lo* represents the current status quo; only a waveform is shown.

arousal can be influenced by frequency/amplitude combination [26], [27]. Metaphors [12], [28], [29] and use cases [12], [28] offer structure, memorability and design language. Spatial displays require additional controls for location and direction, whether body-scale [15], [30], mobile [31], or mid-air [27]. While many parameters are available for VT design, we chose the most established (time-varying frequency and amplitude) for Macaron’s initial implementation.

B. Past approaches to VT design

Past editors – e.g., the Hapticon Editor [32], Haptic Icon Prototyper [33], posVibEditor [34], Vivitouch Studio [35], and Haptic Studio (www.immersion.com) – are track-based, with graphical representations to edit either waveforms or profiles of dynamic parameters. Additional features (e.g., spatial control or mobile interfaces) are surveyed in [36].

A library of effects is critical for haptic design tools [36]. Most existing tools support feature saving/loading, and some have an internal component library [32], [33], [35]. However, previous implementations were primarily *compositional*, employing building blocks [24] rather than complete artifacts. Example use was not studied.

Large VT libraries contain complete artifacts, but impose a serious constraint on their use. In the Immersion Touch Effects Studio library, underlying structure and design parameters are hidden and cannot be incorporated into new designs. VibViz [12] features 120 VT examples with visualizations searchable by several taxonomies, but the selection model is all-or-nothing. FeelCraft [7] proposes a community-driven library of feel effects [8] for simple parametric customization and re-use. While end user customization-by-selection is important [11], experts need a more open, editable model, just as web designers rely on full access to source code with recent tools allowing search and easy incorporation [5].

C. Examples in non-haptic design

Problem preparation – also known as the “problem setting” [37] or “analysis of problem” [1] step of design – involves immersion in the challenge and drawing inspiration from previous work. Both may come from the designer’s experience, *repertoire* [37] or exposure to a symbolic domain, e.g., mathematical theorems and notation [38].

<i>hi</i>	Full access to gallery examples, with keyframes visible and selectable for copy and paste. Simulates source visibility, e.g., viewing the source of a web page or having access to a .psd PhotoShop document.
<i>sample</i>	Hides underlying parameters of frequency and amplitude, whereas waveform regions (underlying keyframes) may be copied and pasted into a design, simulating example mixing in absence of visibility into underlying construction. While possible to see underlying representation by copying the entire example, the steps are indirect and inconvenient.
<i>vis</i>	Reveals underlying parameters, but hides keyframes, parameter scales, selection and copy/paste features. The inverse of <i>sample</i> , it exposes example structure, but does not support incorporating example elements into a design.
<i>lo</i>	Supplies a “black box” outer representation. Playback and visualization of the complete vibration reflect the status quo of non-visible, non-mixable example libraries.
<i>none</i>	No examples present.

TABLE I: Macaron tool alternatives, varied on dimensions of internal visibility and element incorporability.

To this end, external examples are critical in inspiring, guiding and informing design [2], [3]. Industrial designers collect objects and materials; web designers bookmark sites [3]. In graphics and web design, *design galleries* organize examples to be immediately at hand [5], [13]. Example-based tools often use sophisticated techniques to mix and match styles and content [39]: this requires immediate access to the examples’ underlying structure.

III. APPARATUS DESIGN

To investigate VT design in the context of examples, we required a platform that would expose users’ natural procedural tendencies. Our Macaron design gallery is simple, flexible, and extensible. In this work, we add multiple types of example access to polished implementations of familiar concepts: *tracks*, *envelopes*, and *keyframes* (Figures 1,2).

Tracks are the accepted language of temporal media editors (video, audio, and past haptic efforts [32]–[34]). We provide tracks for perceptually important “textural” parameters (amplitude and frequency); the user accesses periodic and time-variant aspects by manipulating their *envelopes* using *keyframes*, with linear interpolation in-between. Users double-click to create a new keyframe, click or drag a box to select, and change or delete a selection by dragging or with the keyboard. A waveform visualization reflects changes.

Macaron’s example access features are inspired by more recent graphics and web design galleries [5], [13], [40], which show examples side-by-side with the editor. Other implemented features, critical for polished creative control [36], include real-time playback, time control (scrubbing) copy-and-paste, undo and redo, and muting (disables realtime VT output). To support its use as an experimental tool, user interactions are logged; start / stop buttons allow the user to indicate when they began and completed their design process.

Macaron was built with HTML5 and JavaScript, using



(a) Heartbeat. (b) Cat. (c) Lightning. (d) Car. (e) Snow.

Fig. 3: Animations used as design tasks, in presentation order. Heartbeat expands in two beats; the cat’s back expands as breathing and purring; lightning has two arhythmic bolts; the car oscillates up and down, and makes two turns: left then right; snow has three snowflakes float down.

React, Reflux, D3, and Audiolet¹. Real-time sound synthesis drove a C2 actuator. To leave hands free for keyboard and mouse, the C2 is attached to a wristband; we simulate the design process for a wrist-worn wearable (as in [12]).

Evaluation Versions: To study how examples impact design, we made four gallery versions by sampling two theoretical dimensions of example access: element *incorporability* and internal parameter *visibility* (Figure 2, Table I). We hypothesized these would affect users’ design processes, e.g., incorporable examples would encourage “mixing and matching” of examples, visibility might provide insight.

We compared these versions with each other and with a non-example version: *none*. In all versions with examples, the user can play or scrub the example, feeling it and seeing the waveform visualization. We did not allow users to modify the examples, to avoid study workflow confounds. To populate the gallery, we chose or adapted seven examples from [12], piloted them to confirm example variety, then regenerated keyframed versions with Macaron.

IV. STUDY METHODS

Participants were tasked with creating a sensation to accompany five animations (Figure 3) – SVGs (scalable vector graphics) which can be played or scrubbed by the same means as navigating Macaron’s time control. We chose animation variety (concrete to abstract) and complexity to inspire non-obvious solutions without overwhelming.

Participants were first trained on *none* with no animation, then presented with five animation/version combinations. As the least crucial source of variance, animations were presented in Figure 3’s constant order, while interface versions were counterbalanced in two 5x5 Latin square designs. Thus, each participant encountered each animation and each interface version once; over all participants, each animation/version combination appeared twice, with Latin squares balancing 1st-order carry-over effects. This design confounds learning with animation task. We believe this is an acceptable tradeoff at this stage, allowing us balance interface order with a single participant session of reasonable length (1-1.5h).

V. RESULTS

We targeted a study size of 10 complete participants for a balanced Latin square design, and a manageable sample

¹facebook.github.io/react, github.com/reflux, d3js.org, github.com/oampo/Audiolet

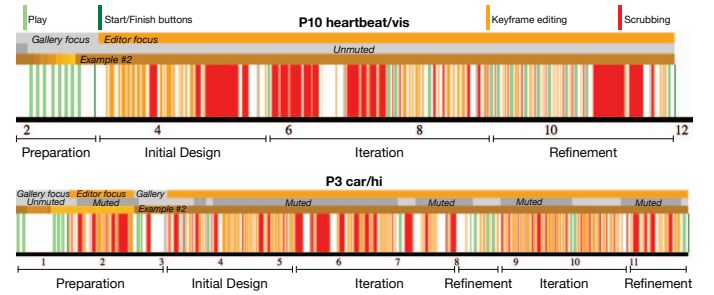


Fig. 4: Log visualizations showing archetypal design process. Top: P10’s heartbeat/vis condition (an “ideal” version). Bottom: P3’s car/hi condition (variations: a return to example browsing after editing, repeated refinement, muted editing).

size for rich, exploratory, qualitative analysis. 13 untrained participants were recruited: P1-10 (7 female, ages 22-35) completed all five tasks, while I1-3 (2 female, ages 29-45) only completed the first three due to time restrictions. Because I1-3 (and P9) all had the same interface order (lo, none, vis, hi, sample), we suspect that beginning with ‘sparse’ versions gave insufficient insight into how to design quickly enough to finish the study. I1-3 showed no distinct patterns beyond this; we leave their data for future analysis.

Analysis and Data: A team member trained in qualitative methods analyzed screen recordings, interviews, and logs with grounded theory methods (memoing, open & closed coding [41]) and thematic analysis and clustering [42]. We visualized logs using D3 (Figure 4). We chose a qualitative analysis because our goal was to capture the design process, not compare Macaron with previous tools. Our analysis exposed three major qualitative findings, discussed below.

Tool Usability: Overall, the tool was well received, described as “easy to use” (P1), “well made” (P5), “pretty neat” (P9), “the templates help a lot” (P3).

Completion time: Overall mean task completion time for P1-10 was 5m48s (median 4m48s, sd 3m52s, min 40s, max 18m23s). We conducted two one-way ANOVAs on completion time; neither interface ($p = 0.87$) nor task ($p = 0.64$) had a significant effect.

A. Archetypal Design Process

Log visualizations (Figure 4) show that users could and did employ Macaron for all key design stages: preparation, initial design, iteration, and refinement. All participants followed this sequence. Some omitted one or more steps depending on personal style and strategies for using examples (below). We list observations of the basic process in Table II, to document behaviour and frame discussion.

B. Micro Interaction Patterns Enabled by Tool

Several small-scale patterns further characterize behaviour within the archetypal process.

1) *Different paths through the interface:* We saw three design-path strategies.

– *Time* (Figure 5; P1,2,3,4,7,9): proceed through the timeline, creating amplitude and frequency at the same time.

Prepare	All participants began with a problem preparation step [1]. They played the animation to understand the problem, then typically looked at several (sometimes all) examples. Only P2, P8, and P9 had a task where they did not begin with an example. Otherwise, participants browsed examples, chose a best match to the animation (“ <i>I was trying to find the best match with the visual</i> ” (P7, heartbeat/hi)), then transferred into initial design. Participants rarely returned to examples for more exploration; only P3 (car/hi) and P5 (car/lo) switched to a different example after beginning their initial design. Preparation is characterized by a large number of plays and example switches: on average, 47.45% of all session plays were before the first edit (sd 30.15%), and participants switched examples an average of 6.75 times (sd 5.17).
Initial Design	Participants either used their example choice to help create their initial design, or ignored it because it wasn’t close enough to what they wanted to do. Participants typically recreated the example in their editor by copy/paste of the entire design (P1,2,4-8,10) or sometimes a component (P3,10) in incorporable conditions (hi and sample), or by manually recreating the design (P5,6) or a component (7,10) with vis. In the lo condition, we only observed P5 somewhat recreating an example. Occasionally, participants would create a new design loosely based on the example rather than recreating it (P3,4,6-8), when using the <i>Inspire</i> example use strategy (described later).
Iterate	Participants refined designs with longer periods of editing typically book-ended by playing the entire design (discussed as “real-time feedback” micro interaction pattern). In some cases, especially when the example was “close enough”, participants skipped iteration (<i>Adjust</i> or <i>Select</i> example use strategies, described later).
Refine	Smaller changes forecast design conclusion, e.g., incremental global changes: constant frequency (P1,2,5,6,10), alignment (P1,3,6), or pulse height adjustment (P1,3,8,10). This step is sometimes visible in activity logs, as most participants (P1,3-10) exhibited more frequent plays of the entire design, and shorter periods of editing/scrubbing. Occasionally, participants repeated larger iterations and refinement (P3 car/hi, Figure 4).

TABLE II: Steps in observed archetypal design process.

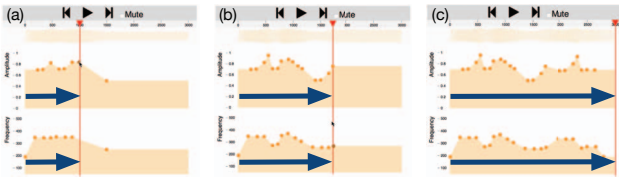


Fig. 5: P9’s cat/none design progressed sequentially in time. Note the red playhead helping alignment in (b).

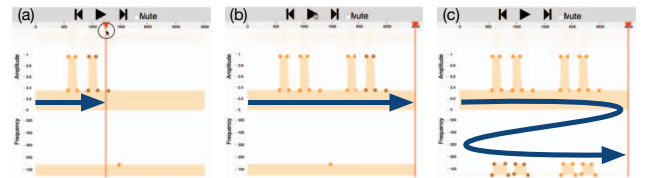


Fig. 7: P10’s heartbeat/vis design progressed by track. Amplitude was developed first, then frequency.

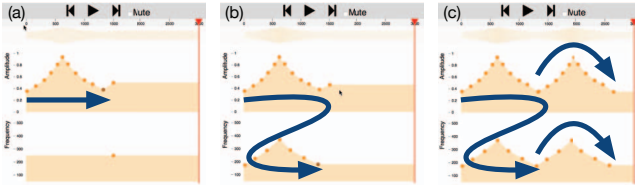


Fig. 6: P6’s car/lo design progressed by component, developing the component then repeating it.

– *Component* (Figure 6, P1,4,6,8,10): iterate on a design element, then repeat or copy/paste it later in time.

– *Track* (Figure 7, P2,3,6,7,8-10): proceed through one entire *track* (typically amplitude), then the other one.

Strategies were often combined hierarchically. P6 developed a car/lo component by track (amplitude, then frequency). Wanting additional flexibility, P1,3,7 requested copy/paste *between* tracks: “*The one thing I found missing was copy and pasting between amplitude and frequency*” (P7).

Further showing diverse workflows, participants requested more powerful controls to work with keyframes as a group, such as widen (P5), reverse (P7), shift everything (P9), move up/down and smooth (P4). Other requested features include looping (P1), hovering over a point to see the value (P1), more detail through a zoomable interface (P4).

2) Alignment and Copy/Paste are Precise, Convenient:

Precision was valued; alignment and copy/paste were used to achieve it. Alignment was sought both in time and to keyframe values. A common technique (Figure 5b) was to use the red playhead like a plumb-line to align keyframes

with animation features (P1-5,7,9,10) and between the two tracks (amplitude and frequency) (P3-5,7,9,10): “*Using that red arrow thing and placing the dots when it makes the heart-beat*” (P2). Some participants, including those who used the plumb-line, requested more refined alignment features: “*I couldn’t keep it straight*” (P1).

Copy/paste was used for improved work efficiency (especially helpful during initial layout or when creating long or repeating designs) and precision: “*Copy and paste...was also the most precise, because if you feel like it’s a perfect fit, you can use it exactly*” (P6). Correspondingly, conditions without copy/paste (i.e., lo and vis) took additional effort: “*It’s harder...because there’s no copy and paste*” (P5). Precision also depended on context: “*For monitoring someone’s health, you would have to be very accurate*” (P9).

3) *Editing and playback*: During iteration, participants edited in bursts of primarily scrubbing activity, bookended by full playthroughs. They took time to realize each new version of the design before observing an overview. When editing, participants scrubbed back-and-forth, varying speed (P1-4,7,9,10), and dragging keyframes to try ideas out (P1,3,4,7,9,10) Figure 8. This feature was valued by those who used it: “*The real-time part is pretty important*” (P1); some rarely played, showing more frequent or longer periods of scrubbing instead (P2,9,10). Others rarely scrubbed (P5, P8), possibly to have an overall sense of the design: “*Trying to get a general sense of how it might feel*” (P8). P3, P4, and P7 all exhibited focused editing with mute enabled, unmuting for the bookended play sections; others did not use muting.

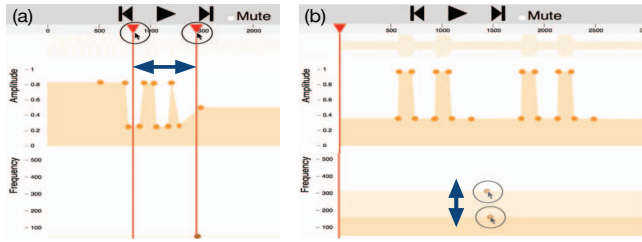


Fig. 8: Participants used real-time feedback to explore, both (a) in time by scrubbing back and forth (P3 lightning/lo), and (b) by moving keyframes (P10 heartbeat/vis).

4) *Encoding and Framing*: Some participants encoded parameters using consistent rules, often aligned to events like heartbeats or lightning bolts. Others sought to create moods or metaphors for sensation.

Encoding was most visible in the lightning task, where participants represented lightning bolts in regular ways: “if there was a lightning bolt on the left, I put amplitude and frequency a little longer than a lightning bolt on the right” (P9). When the animation had two simultaneous bolts, several (P2-4,7,9) encoded it by superimposing two bolt representations on top of one another. Participants were forced to reframe their encoding strategy: “...two [lightning bolts]...I divided it into two equal partitions, .6 and 1” (P7).

Encoding failed when participants did not find a direct mapping: “When the three [snow flakes] come together I think my strategy broke down” (P7). Metaphors helped in these cases. Car took extra imagination, either for the experience of driving (P6, P8, and P9 didn’t drive), or because it’s hard to “know what it would feel like on the wrist” (P1). P6 describes her process for both lightning and snow as using mood: “...what I think the mood is...like snow fall, it’s kinda like, very gentle and calm” (P6).

C. Example Use

As seen, examples played a major role in users’ design processes. Analysis revealed the effect of examples to be more nuanced than a one-to-one mapping of the theoretical dimensions of incorporability and visibility. Emergent themes were instead organized on the *role* of examples: as a *direct starting point* for each design; and to *indirectly scaffold learning* throughout a session. The latter was related to additional themes: task difficulty and individual differences.

1) *Direct example use – task starting point*: When participants *prepared* for each task by browsing to find a best-match example, then using it as a starting point, they did this with a spectrum of strategies. These strategies, elaborated in Table III, range from Ignore (examples not used) to Select (an example was the final design).

2) *Indirect example use – observe how to design*: Over the course of the session, participants used underlying structures of examples to understand how to design VT icons. This was most evident in the none or lo condition after participants were first exposed to examples: “I sort of remembered” (P4 car/none). Some explicitly described learning: “It gave me

Ignore	Deliberately do not choose an example, through either lack of match: “I didn’t [find] the examples that I wanted” (P1); a desire to challenge themselves or be creative: “I wanted to do my own thing!” (P9); or difficulty in using the examples.
Inspire	Choose an example, but do not explicitly copy/paste or replicate it in the editor; instead, design based loosely on example parts, sometimes as an adaptation from memory: “I just tried to remember what the keyframes were like before, and then I modified it” (P6 car/lo).
Template	Choose an initial example, but alter it considerably. In this case, participants use the example to expedite the process.
Adjust	Find an initial example, skipped major iteration and went directly to the refine stage, sometimes because the example was a close match. To enable this, some participants wanted a more powerful manipulation methods, like inverting (P7).
Select	Copy/paste an example (or manually recreate it), then do not modify; sometimes because the example seemed to match: “...copy and paste, then confirmed it was the same.” (P5)

TABLE III: Strategies used by participants to directly use examples as a starting point. Ignore and Inspire did not start with copy/paste; Template, Adjust, and Select did, with varying amounts of editing afterwards. When copy/paste was not available, manual re-creation was used as a stand-in.

a general idea of thinking in big shapes rather than little dots” (P9 lightning/vis).

Most participants commented on the difficulty or ease of their task (P1-5, 7-9). Task difficulty was connected learning (“It’s easy...maybe it’s more experience” (P4 snow/lo)) and individual differences. Some people were motivated to learn, and challenge themselves; others were not.

Connections between these factors are complex and difficult to unravel with this data. We speculate on the utility of flow theory [38] as a useful lens to connect these issues, as it considers creativity, education, and the relationship between perceived challenge and perceived ability. We plan to use it to frame future exploration.

VI. DISCUSSION

We discuss implications for design, then limitations we hope to progress on with future work.

A. Implications for Design

1) *Expose example structures for learning*: When exposed to examples’ underlying structure, participants are able to build their repertoire and learn VT design conventions like “big shapes” (P9). Such scaffolding is particularly crucial in an environment where experienced VT designers and training possibilities are rare. Whether through exploratory tool use or structured with online training programs, examples can expand the VT design practices available to novice designers.

2) *Examples as templates*: Participants typically copied an example first before iterating and customizing, suggesting a template model of modifiable source documents as a way to expose structure and reduce effort for designers.

3) *Example Recommender*: The time participants spent searching for the suitable examples suggests a recommender system could be very valuable. AI techniques might recommend examples similar (or dissimilar) to a source stimuli, as

with previous tools in other sensory modalities [5] and VT visualization tools like VibViz [12].

4) *Clarify example context*: Participants often repeated gallery searches for each new animation; they needed to compare examples alongside the target graphic. In addition, though our examples were designed independently of our animation tasks, some participants showed confusion about whether they were supposed to match. Clarifying the context for each example, by presenting it either in connection to its original design goal or as a candidate for the participant's current goal, will help participants choose an example.

5) *Hideable examples*: Some participants wanted to be individualistic with their designs and actively disliked the most powerful `hi` condition, saying that the `none` condition was cleaner, or that while examples were helpful to learn, they felt “more creative” with fewer examples present. A hideable gallery, which can be opened when needed but kept hidden otherwise, could accommodate user preference. An intelligent gallery could even time example appearances or suggestions to occur at helpful design stages, e.g., by recognizing by activity patterns [1], [4].

6) *Realtime “prefeel” then render*: Macaron's real-time feedback supported exploration, with full play-throughs providing an overview or evaluation in-between editing sessions. In addition, P4, who was familiar with haptics, felt that the scrubbing synthesis was “muddy” relative to waveforms pre-rendered with audio tools – a common challenge, noted also by the researchers but deemed suitable for this study. While we hope this technology deficit inspires improved realtime rendering algorithms, it also suggests an explicit workflow compromise. Many video editing and compositing tools show a low-resolution previsualization in design mode; a clip is then fully rendered for playback. For tactile design, coarse, “prefeel” sensations would be synthesized for immediate feedback during a rough design stage, and a high-fidelity rendering generated for less frequent play-throughs. This could help computationally demanding, perceptually-based models or multi-actuator setups (e.g., tactile animation [36] as a prefeel for tactile brush [30]).

7) *Tool flexibility*: Macaron was used in very different ways depending on the participant. Some progressed by time, by track, by component, or a combination thereof. Some mirrored frequency and amplitude, using them together, while others used them to express different ideas. This suggests that tools should be flexible and accommodate different strategies; perhaps offering a choice to group by parameters (e.g., [36]) or work along parameter tracks (e.g., [33], [35]).

8) *Alignment tools*: Participants frequently used the play-head for alignment, finding locations in the video or aligning points between amplitude and frequency. Participants requested using modifier keys to align points (as in other editing tools), or a visualization of events in video. This suggests several features, providing ability to:

- Align comparison sensations from each modality - visual or audio sensation alongside VT.
- Place anchors for attaching a VT sensation (or keyframe within it) to a point in a target visual or audio sensation.

This might be automatically assisted, e.g, with video analysis techniques to find scene changes.

- Automatically align keyframes to nearby keyframes, or use a modifier key to constrain or nudge keyframe movement.

9) *Reuse*: Copy/paste, especially from a template, speeded design and facilitated otherwise tedious approaches. Several participants made use of element repetition, which had to be re-done upon design re-framing. While copy/paste was helpful, more powerful repetition tools (e.g. looping, and “master templates”, as in PowerPoint) would likely find use by many designers.

10) *Automated Encoding*: Some participants applied consistent rules in translating an animation to a tactile rendering – e.g., representing left/right lightning bolts differently in the lightning animation, or directly matching amplitude to up-down motion in the car animation. Some of these practices might be automated into generative rules. For example, video analysis could detect up/down motion for a visual object, and translate that automatically to a level for amplitude, similar to how motion trackers can track a moving object and link that to position of an animation; or, a designer might want to specify the mapping. More complex parameterizations could provide a useful tool for expert users, much like how `fmod` allows for parametrized audio in game design.

B. Limitations & Future work

Limitations in our study suggest future lines of inquiry: following up on additions study factor by deploying online.

1) *Study factors*: Our Latin square design allowed qualitative comparison of several gallery variants, but did not have the power for comparative statistical tests between the alternatives. Meanwhile, five design tasks presented in a uniform order did not permit systematic insights into other factors: learning, or task features such as abstractness and complexity. Flow was identified after-the-fact as an important framework for future analysis, but only after our study was designed and data was collected.

Our proposed example-usage dimensions of visibility and incorporability were a useful starting point, but did not line up well with the task processes that people actually used with Macaron. We did see behaviors that aligned well with *learning* and *design-starting* from examples, as well as hints of a more rich and nuanced view of what makes examples useful and in what way.

First, the examples-as-starting-point strategies actually used (Table III) suggest that visibility and incorporability at minimum are not quite right and probably insufficient in dimensionality – there is a concept of edibility regardless of starting point; whereas incorporability could entail editing, but certainly requires an example as a start.

Additionally, observations (including details not reported due to space limits) suggest other factors that influence example use, e.g., *difficulty*, from task, interface and personal confidence and experience; and *task*, from task complexity and abstraction, user strategy, e.g. encoding and metaphor, and user confidence and experience. These hints are far from orthogonal, and will require further research, with focus

turned to elements like task abstraction and user background, to disentangle and prioritize.

2) *Online deployment*: Triangulation will be helpful in studying factors like difficulty, task abstraction, and user background. In this study, Macaron was deployed and studied locally. We were able to validate the editor's design support and utility of its logging methods, and expose many interesting insights into natural end-user design practices.

Our next plan to answer these questions is to deploy Macaron at a larger scale: online, as a free-to-use design tool for the haptics community, with an initial study in haptics courses. This will allow research *in-situ* with larger, more quantitative, remote-based methods for data collection, triangulated with the less scalable qualitative methods used in-lab. Interaction logs, use statistics, and A/B tests will help us further develop Macaron as a tool for VT design and more generally as a lens for the haptic design process.

VII. CONCLUSION

In this paper, we present initial findings from a vibrotactile (VT) design gallery, Macaron. This tool revealed insights both into how examples are used in VT design and implications for other VT design tools. Macaron was implemented using web tools, offering a unique opportunity to follow-up on the design process we observed here, helping designers to create engaging experiences while understanding their craft.

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