End-user Customization of Affective Tactile Messages: A Qualitative Examination of Tool Parameters

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Abstract

Vibrotactile (VT) signals are found today in many everyday electronic devices (e.g., notification of cellphone messages or calls); but it remains a challenge to design engaging, understandable vibrations to accommodate a broad range of preferences. Here, we examine *customization* as a way to leverage the affective qualities of vibrations and satisfy diverse tastes; specifically, the desirability and composition of VT customization tools for end-users. A review of existing design and customization tools (haptic and otherwise) yielded five parameters in which such tools can vary: 1) size of design space, 2) granularity of control, 3) provided design framework, 4) facilitated parameter(s), and 5) clarity of design alternatives. We varied these parameters within low-fidelity prototypes of three customization tools, modeled in some respects on existing popular examples. Results of a Wizard-of-Oz study confirm users' general interest in customizing everyday VT signals. Although common in consumer devices, choosing from a list of presets was the least preferred, whereas an option allowing users to balance VT design control with convenience was favored. We report users' opinion of the three tools, and link our findings to the five characterizing parameters for customization tools that we have proposed.

Index Terms: H.1.2 [User/Machine Systems]: Human factors—Haptic Tools, End-User Customization;

1 Introduction

Increasingly present in consumer electronics, vibrotactile (VT) stimuli generate mixed reactions. Genuine utility is possible, yet a given user may find the stimuli themselves unsuitable in their context, but cumbersome if not impossible to modify. A common example is call or message notifications in cellphones, generally provided with a limited set of basic vibrations (or perhaps just one) that cannot accommodate the broad range of user preferences.

This problem is not merely aesthetic: mappings between stimuli and their meanings can be hard to learn when mnemonic links are not apparent, and meanwhile users may wish to deploy salience (e.g. due to amplitude, duration and repetition) according to an intensely personal scheme. When mappings and salience do not work well for an individual, utility is overwhelmed by irritation; the signals are relegated to minimal roles or disabled altogether.

In this research, we are exploring the further premise that appropriately leveraging *affective* qualities of haptic stimuli in interface design could change this. Not only might "design for affect" add to the variety, pleasure and fun of using electronic devices, it could be exploited to enhance functional benefits by making individual signals more intelligible and memorable.

However, incorporating affect into haptic design is not easy. Affective responses to synthetic haptic stimuli are not yet well catalogued, precluding a heuristic approach at this time. Individual differences in both perception and affect further complicate the matter [13, 14]. While academic and industry experts are progressing towards a better understanding of affective response and design principles, we consider a different approach: *empower ordinary users, having no previous design knowledge, to design or customize haptic feedback for their own preference and utilitarian needs.*

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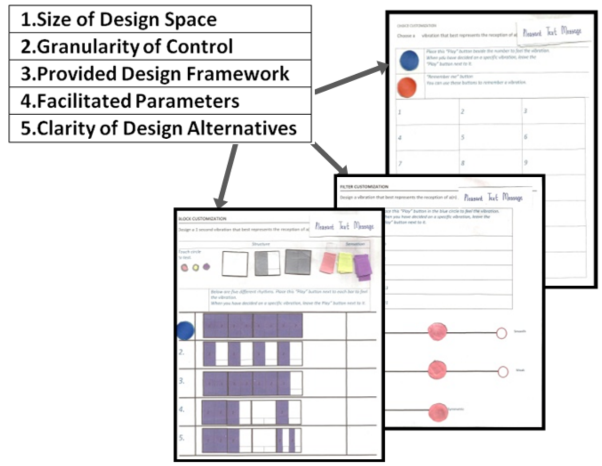


Figure 1: Study paradigm: Five proposed customization tool parameters (top left) and three customization tool concepts (low-fidelity prototypes) which capture variance in these parameters.

A first question is thus: ***(Q1): What characteristics will make a VT customization tool usable?*** The design space for VT stimuli appears large if we consider all combinations of the controllable variables (e.g., VT frequency, amplitude, waveform and even rhythmic presentation). Yet, many are perceptually similar when rendered, and this further depends on device characteristics [16]. A typical user, with a limited conceptual model of this structure and its non-independence, would get little traction if given these comprehensive, low-level controls. Thus, we investigate the productivity and desirability of a diverse set of tools that might support typical end-users in customizing haptic effects, with the dual hope of such utilities leading to better tools for haptic designers as well.

The second question is whether given a manageable tool, this is desirable. Specifically, ***(Q2) Do users* want *to customize vibrations for their everyday devices?***

Finally, as a step towards understanding affective preferences themselves, we wonder ***(Q3): What kind of vibrations do people design when given the opportunity?***

In this paper we focus on Q1, and establish insights and future directions for Q2 and Q3. We identified parameters that characterize existing customization tools, then evaluated their manifestations in three haptic tool concepts via a Wizard-of-Oz (WoZ) study where we asked participants to design urgent and pleasant cellphone notifications (Figure 1). Our contributions include:

- Five dimensions for VT design and customization tools;
- Three tool concept prototypes that capture this variation;

- Quantitative and qualitative data on user opinions of the three concepts, viewed in context of the proposed tool parameters;
- Informal qualitative data on vibrations designed by users.

2 Related Work

2.1 Haptic Design

Haptic effects can take many forms, the most common of which is vibrotactile (also the focus of our work). By "haptic design", we refer to creating haptic effects to be rendered by a haptic display. Existing haptic devices vary considerably in their capabilities, leading to a tight coupling of effect design to device development. Haptic designers must intimately understand technical device parameters, and currently must usually design within that technical space. For example, VT designers can typically vary frequency, waveform, amplitude, duration and rhythm [16, 9]. Documentation of a mapping from technical space to users' perceptual space for tactile stimuli is underway [16, 4, 17]. Here, we have structured our proposed tools in an *intuitive and perceptual* rather than a *technical* control space, positing that this will lead to more satisfying results, particularly for inexperienced designers.

VT effects have been designed both to communicate information (see [9] for a survey) and affect [5]. To ensure effective design, haptic designers typically use iterative design and user evaluation of haptic stimuli [9]. However, this approach has been less successful for haptic effects with affective qualities; convergence is difficult in the absence of adequate evaluation metrics, and in the face of notable individual preference differences [14].

2.2 Haptic Design Tools

The haptic community has proposed a number of design tools in the past decade, each aiming to reduce technical knowledge required for design and thus opening the domain to a wider audience.

Categorization of Tools: Paneels et al. [12] categorizes haptic design tools based on their support for one vs. multiple actuators; and type of representation: a direct signal (e.g., Haptic Icon Prototyper [15], and Immersion's Haptic Studio [3]) or an indirect, metaphor-based view (e.g., VibScoreEditor [7], TactiPed [12]). We find that this organization does not adequately differentiate tools for end-user customization. For example, all of our prototypes use indirect representation and currently support one actuator, yet vary in other substantive ways.

Creation and Modification: All the tools we have seen are primarily concerned with creating haptic effects. For example, to create vibrations, Hong et al. [6] mapped user touch input (e.g., pressure, location) to amplitude and frequency, an approach found useful for prototyping and demonstration but not suitable for modification of effects. Other tools support both creation and modification of the effects. The Haptic Icon Prototyper provides more flexibility by allowing users to combine short haptic snippets in a sequential or parallel form along a timeline [15]; one of our three concepts (*Block*) uses a similar approach. With a focus on creation and modification, all the above tools provide fine-grained control over stimuli. For a modification-only tool, the importance of various tool requirements can shift – for example, convenience might outweigh design control. Here, we are also primarily interested in modification or customization of pre-existing templates, as it could be a more practical approach for users without design knowledge.

Audience: Existing tools differ in the design knowledge they require and thus usability for ordinary users. Some (e.g., VibScoreEditor, TactiPed) specifically target ordinary users; but despite their promising evaluations, they have remained in the academic domain. A notable exception is the iPhone tapping tool for creating customized vibrations for a user's contact list [2].

2.3 Challenges & Potentials of End-user Customization

While these tools typically aim to be accessible to ordinary users, these users' ability to design has rarely been investigated. Oh and Findlater [11] studied custom gesture creation by this group, and found they were able to create a reasonable set of gestures but tended to focus on variations of familiar gestures. Customization might suit at least some end-users better than creation, affording satisfaction instead of frustration.

We can gain insight from customization literature in software engineering on factors involved in end-user customization of software applications. Sense of control and identity, frequent usage, ease-of-use and ease-of-comprehension in tools allowing customization engender takeup [10] while customization is discouraged by lack of time or interest, and difficulty of customization processes [8].

3 Conceptualization of Haptic Customization Tools

As a first exploratory attempt to conceptualize haptic customization tools, we examined, brainstormed and discussed characteristics of existing design tools in the haptic and other domains. As a result, we propose five parameters along which design and customization tools can vary, including: 1) size of design space, 2) granularity of control, 3) provided design framework, 4) facilitated parameter(s), and 5) clarity of design alternatives (Table 1). We posit that these parameters can influence users' perception of flexibility and effort to design haptic effects and consequently, their preference and tool choice.

Although desirable, dependencies among the parameters make it infeasible to study the effect of each parameter in isolation or to examine users' opinions about all variations of the parameters in a meaningful study. Existing tools co-vary on many of these parameters and a realistic study would need to examine many together. Thus, we define three haptic customization tool concepts that are considerably different, capture variations along all tool parameters and are practically interesting. Our concept prototypes borrow from existing tools in haptic and photo editing domains.

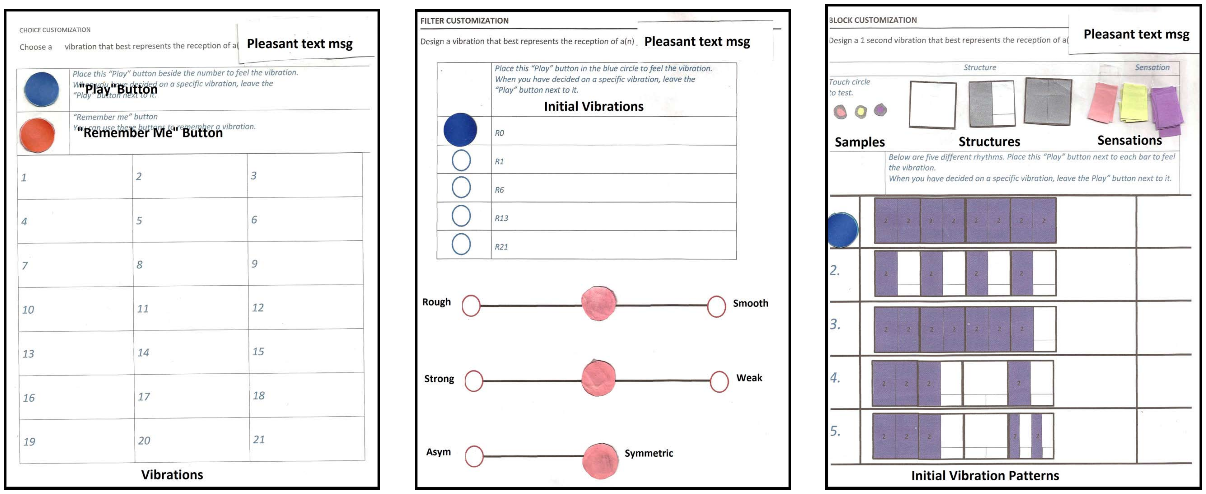
3.1 Three Customization Tools

We begin by describing our three proposed tool concepts, implemented as paper prototypes, then use these and existing tools to explain our proposed tool characterization parameters. We chose to evaluate manually operated low-fidelity prototypes because a tool concept can be implemented in various ways differing in interface elements or interaction style and we wanted to avoid reactions focused on those differences. In contrast, a paper prototype allows users to flexibly interact with the tool concept, thus we could obtain reactions focused on conceptual differences of the tools.

1. *Choice* *(baseline: minimal customization, focuses on convenience)*: This tool models a conventional way of customizing ringtones and other auditory alerts on consumer electronics, wherein users are provided with a list of vibrations to choose from. Our prototype (Figure 2a) lists the vibrations in a tabular structure where rhythm varies by row and VT frequency by column. The user places the *Play* button over each vibration number to signal to the experimenter (acting as a computer) to play the vibration. The *Remember Me* buttons are used to mark some vibrations and facilitate future comparison and choice.

2. *Filter* *(more power, still emphasizes convenience by allowing high level control)*: Inspired by color adjustment filters in photo editing tools like Adobe Photoshop, users have a small initial set of vibrations and three perceptual filters to vary roughness, strength, and symmetry. These dimensions have repeatedly emerged as the most salient and important [16]. *Filter*'s paper prototype (Figure 2b) includes five initial vibration patterns in the upper rows, and three sliders representing the filters at the bottom. To feel a vibration, users need to choose a rhythm at the top with a particular setting of the filters at the bottom.

3. *Block* *(trades off convenience for greater control over the stimuli)*: Derived from the Haptic Icon Prototyper [15], a vibration is made of a sequence of vibration blocks and to modify a vibration, users change the individual blocks in the sequence using the



(a) *Choice* concept: a 7x3 table of vibration presets lies beneath blue *Play* and orange *Remember Me* buttons. In this paper prototype, moving the blue or orange sticker to one of the vibration cells represents (in a real device) cursor-selection of a vibration and then the execution of that function on it. In our WoZ study, the experimenter executed this response manually, s.t. the participant felt the selected vibration on the display device.

(b) *Filter* concept: user can apply 3 filters (bottom) to 5 rhythm presets (top); the presets cannot otherwise change. The roughness and strength filters have three settings each, and the symmetry filter has two. The blue *Play* button again selects a preset. Here, the movable orange *Level* circles show the current filter settings for playback (shown: default setting).

(c) *Block* concept: lower area visualizes the time sequence for 5 initial rhythms (purple indicates vibration-on, and white is silence, over a 500ms period). Users can modify the rhythm itself by selecting and overlaying a different block structure (top middle) and an available block sensations (colored rectangles on top right). The 3 small colored circles (top left) allow users to try the 3 block sensations (45Hz, 75Hz, 175Hz) before using them.

Figure 2: Three customization tool concepts

available vibration blocks. With our prototype (Figure 2c), users can start from one of the five vibrations at the bottom, then choose a block structure (silence, half vibration, and full vibration) and one of the three block sensations from the top and place it at the desired location along the chosen vibration sequence. They can test their design by putting the blue circle (*Play* button) beside the vibration.

3.2 Proposed Tool-Characterization Parameter Space

We were able to identify five parameters that described the variation we observed during our review of existing customization tools. Table 1 relates these parameters to our three concept prototypes (*Choice*, *Filter* and *Block* customization). These parameters are not orthogonal or independent: for example, providing finer control over stimuli will increase the size of the design space.

1) Size of Design Space Accessed by the Tool: The size of the design space refers to the number of distinct stimuli that a tool can create; it depends on the design tool and a rendering haptic display. The tool's "perceptual size", meaning the number of *perceptually distinct* stimuli that it can create, is also important but harder to quantify. For example, if people can only distinguish a subset of stimuli designed by a tool and rendered by an actuator, that subset is the perceptual space for that tool and actuator. The size of design space increases from *Choice* to *Filter* and to *Block*.

2) Granularity of Control: The smallest unit of a stimuli that a user can directly manipulate with a tool can vary from holistic (coarse) to local (fine) control. With *Choice* and *Filter*, users could control a whole 2s vibration by selecting it, but with *Block* they had control over 125ms sub-blocks (by modifying or replacing them).

3) Provided Design Framework: Any design tool inevitably imposes an outline or framework on design. This structure will, to some degree, impose on the user some organization of the design space. Our *Choice* tool provides the tightest structure, by only allowing users to choose from a list of sorted vibrations. *Filter* conveys a perceptual organization of the design space, via the three axes provided. *Block* provides a discrete, block-based outline for the design and organizes building blocks into 3 structures (rhythm management) and 3 sensations (frequencies). As another example, the iPhone tapping tool provides very little structure: vibrations are viewed as variable-length touches to the screen.

4) Facilitated Parameters: The degree and ease of control that a given tool affords for each parameter may vary. Some are promoted by the tool for creation or manipulation of stimuli and take the least or little effort to manipulate. *Block* facilitates control over the rhythm or structure of vibration while *Filter* facilitates control of feel or sensation. Both of these tools to some extent allow control over structure and feel but one is more prominent than the other. *Choice* allows limited control over both feel and rhythm.

5) Visibility or Clarity of Design Alternatives: Tools vary on the extent that alternative designs are provided to users, vs. discovered. Visibility of design alternatives decreases from *Choice* (all stimuli are listed) to *Filter* (all filter combinations are apparent) to *Block* (outline and building blocks are apparent, many versions are possible. Traversal of the design space in a reasonable time must involve discovery).

Table 1: Embodiment of proposed parameters: characterization of *Choice*, *Filter* and *Block* concepts.

Proposed Parameters	Choice	Filter	Block
1. Size of Design Space (for C2 tactor [1])			
Technical:	21	90	2400
Perceptual:	21	$\sim 45-90$	< 2400
2. Granularity of Control	Holistic (Coarse)	Holistic (Coarse)	Detailed (Fine)
3. Provided Design Framework	List	Perceptual	Building Blocks, Outline
4. Facilitated Parameter(s)	Feel, Rhythm	Feel	Rhythm
5. Visibility of Alternatives	High	High	Low

4 Methods

We ran a WoZ study with paper prototypes to examine users' interest in customization and their opinions of our tool concepts.

Setup: We delivered VT effects with a C2 tactor [1], controlled via a control computer's audio channel and audio-amplified; signal and amplification levels were held constant. To maximize dynamic range, participants held the actuator between thumb and index fingers of the dominant hand and worked with one prototype at a time (Figure 3). They used movable paper pieces to specify vibrations; when they pressed the movable blue *Play* button, the experimenter played back those vibrations to them. Participants could not see the control laptop screen.

Stimuli: All vibrations in the study lasted 2 seconds. Vibration duration and other choices for the parameter values were determined based on pilot studies and prior work. We used 7 rhythm patterns (Figure 4) from a larger rhythm set [16]. Initial vibrations and possible alternatives varied for each tool:

1. *Choice*: 7 rhythms (Figure 4) were rendered in 3 frequencies (45Hz, 75Hz, 175Hz), chosen based on pilot studies. Thus, participants could choose from a total of 21 vibrations arranged in a table: the vibrations with different rhythms in rows and those with different frequencies in columns (Figure 2a).

2. *Filter*: We rendered the first 5 rhythms in Figure 4 in 75Hz to represent the middle setting on the strength and roughness filters and the symmetric setting on the last filter. Participants could choose from 18 filter settings ($5 \times 18 = 90$). Entries of Table 2 show changes relative to the default settings, determined by pilot studies and prior work in our group to match the perceptual filter labels.

Table 2: Configurations of each filter setting in the *Filter* tool.

Setting	Change from Default Vibration
Default	No change (75Hz, 5 first rhythms from Figure 4)
Smooth	45Hz, De-amplification of 3dB
Rough	5 ms silence added to middle of each 50 ms vibration
Weak	De-amplification of 6dB
Strong	Amplification of 6dB
Asymmetric	Removal of 2/3rd of vibrations in the first second

3. *Block*: The first 5 rhythms in Figure 4 were initial templates for *Block* customization. To make a new vibration, one could choose one of the 3 block *structures* (silence, half vibration, and full vibration) with one of the 3 block *sensations* (45Hz, 75Hz, 175Hz). Each block had 125ms duration; the full pattern was 500ms, to be repeated 4x in playback. This left 2400 ($[2\ \textit{vibration structures} \times 3\ \textit{sensations} + 1\ \textit{silence structure}]^4 - 1$) design alternatives.

Participants: 24 university students (9 male) participated in a 1 hour study for $10. They came from many fields (engineering, science, management, arts, etc.) and age range (16 [19-29 years], 4 [30-39], 3 [40-49], 1 [>50]). 20 used cellphones or game controllers with haptic feedback on a daily basis. 7 had basic design experience with Photoshop and other video editing software.

Design: We used one independent within-subject factor (prototype, three levels) and counterbalanced order of interface with a Latin square. We also counterbalanced order of designing urgent vs. pleasant notifications, though for each participant, kept the order the same across the three prototypes. We collected: 1) ratings on customization interest (1-5 Likert scale), 2) rankings of the tools on ease-of-use, design control, and preference, 3) comments from participants, 4) time spent on each tool, 5) vibrations designed with each tool for pleasant and urgent notifications.

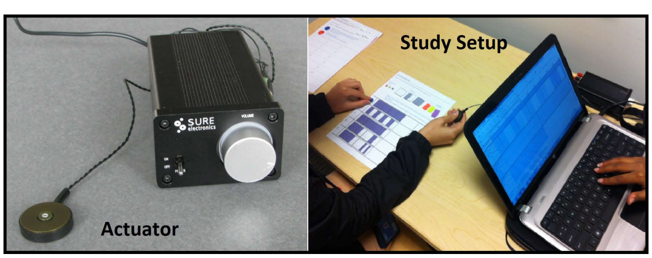


Figure 3: Study apparatus. (Left) C2 tactor and amplifier. (Right) Setup showing a participant working with a prototype and the experimenter playing back the vibrations.

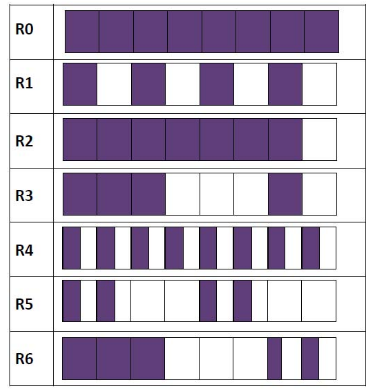


Figure 4: Seven rhythm patterns: Each row represents a vibration pattern which is repeated 4 times in a 2 second stimulus.

Procedures: Study sessions took place in a quiet room. Participants completed a questionnaire on demographics, experience with haptic feedback, and previous haptic, auditory or visual design experience. The experimenter then briefly explained the first prototype and asked the participant to use it to design an urgent and a pleasant notification; repeated this for each tool ($\tilde{1}5$ minutes each); and administered the post-questionnaire above. We also asked which tools they would use if they had all three tools on their cellphone and for what purpose; if they had enough time to design vibrations, and if the labels in the *Filter* tool matched the vibrations.

5 Results

5.1 Comparison of the Tools

We use separate Friedman tests to compare the rankings of the tools on ease-of-use, design control and preference. In the cases of statistical significance, we report follow-up pairwise comparisons using a Wilcoxon test and controlling for the Type I errors across these comparisons at the .017 level, using the Bonferroni's correction.

Ease-of-Use or Usability: Ranking of ease-of-use did not differ significantly across the three interfaces ($\chi^2(2) = 0.8$, $p = 0.67$), suggesting that the usability of the tools were reasonably similar.

Design Control: Participants ranked how well each tool allowed design of an urgent and of a pleasant notification. There was a significant difference of interface for both types of messages (urgent: $\chi^2(2) = 10.94$, $p = .004$, pleasant: $\chi^2(2) = 6.02$, $p = .049$). For both types of messages, post-hoc tests indicated that *Block* was significantly ranked more powerful than *Choice*, (urgent: $p = .003$, pleasant: $p = .041$). Rankings for *Filter* did not significantly differ from *Block* and *Choice* (urgent and pleasant $p > 0.5$).

Preference: Rankings for preference was significantly different for the tools ($\chi^2(2) = 9.69$, $p = .008$). Post-hoc comparisons showed *Filter* was significantly preferred over *Choice*, (p=.006) and *Block* ($p = .012$).

Design Time: According to post-questionnaire, participants generally had enough time; three participants wanted more time for *Block*, the most complex. The average time spent on *Block* (M~12.5m, SD~5m) was higher than for *Filter* (M~7, SD~2.5) and *Choice* (M~6, SD~2.5). This time included creation and playback of the vibrations by the experimenter. As we knew that vibration creation was more time-consuming for *Block*, we did not analyze the timing data statistically. Our observations during the study sessions support the timing data i.e., participants needed more time to think, change, and compare the generated vibrations with *Block*.

Choice of Tools: In response to our question "Which tools would you use if you had all three tools on your cellphone?", 20 participants (83%) chose *Filter*, 10 chose *Block* (42%), and 8 chose

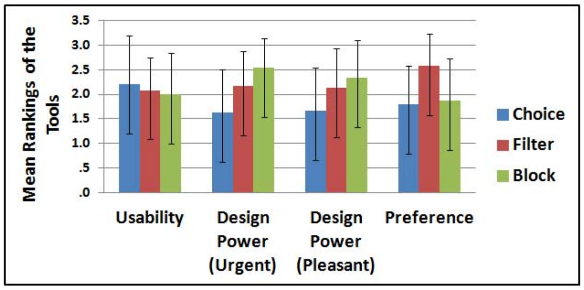


Figure 5: Participants' rankings of the three tools. *Block* was the most powerful while *Filter* was the most preferred.

Choice (33%). Unsurprisingly, many participants mentioned design flexibility and required time as two factors in their decision. According to their comments, *Filter* is *"simple and fast...yet gives flexibility to choose and customize" (P16)*. Interestingly, some participants described *Block* as being *"fun" (P11)*, or for when they are in a *"good mood" (P15)*: *"When I feel that I have too much time and have a good mood, I may like to design a special pattern using the Block Customization. If I don't have any mood or feel lazy, I may use the Choice or the Filter one."(P15)*

A majority (20/24) felt that the filter labels in *Filter* customization matched the sensations. Three said that asymmetric and symmetric vibrations were not very different and one had a similar comment for the strength and roughness filters.

When we asked about the iPhone tapping tool, only three participants had tried it for making custom vibrations, none of whom found it useful. P24 doubted his/her ability to make nice vibrations: *"At first, I thought it would be fun making your own custom vibration, but once I tried the interface, I was not really into it since the vibrations I created were not as nice as the already customized vibrations on my phone."*

P9 wanted some vibration or structure to start from: *"It's simple and not so much patterns to choose from."*

P5 did not find the input mechanism adequate for his/her needs: *"It was really easy to use, but my fingers don't move fast enough to create the rapid vibration I would want to use for urgent messages. And it was hard to make the vibration symmetrical."*

5.2 Interest in Customization

On average, participants stated interest in customizing their vibration notifications ($M = 3.42$, $SD = 1.14$ on a 1-5 Likert scale). Lack or minimal use of vibrations was the main reason for not being interested in customization while recognizing different types of alerts, being unique, adjusting the sensation levels, and concerns about repetitive exposure to unpleasant vibrations were the main reasons for customizing their cellphone notifications.

5.3 Vibrations Designed by Participants

24 participant each designed 6 vibrations (one pleasant and one urgent with each tool) resulting in 144 in total. We provide an informal summary of the vibrations. We imagine that participants might have made different choices if designing for real use, and the WoZ study approach could also have impacted the extent that they explored alternative designs. This might also be the reason for some inconsistencies in the vibrations designed with the three tools.

Overall, participants chose and modified the first three rhythms (R0, R1, and R2 in Figure 4) the most. The order of rhythms on the paper prototypes were the same for all participants and all interfaces. Although this result can be partially due to the presentation order, the same rhythm preferences stood out in another experiment [14]. Unexpectedly, in many cases participants did not choose markedly different rhythms for pleasant and urgent messages. We are interested in knowing if a similar pattern of choices would hold in real life.

With *Choice* and *Block*, over 20 participants (83%) used higher or the same frequency for urgent notification than for pleasant notifications. On *Filter*, over 17 participants (70%) used the strong and symmetric settings for both pleasant and urgent messages. The participants varied the rough/smooth and rhythm settings the most to differentiate pleasant and urgent messages. Only 8 participants (33%) used the asymmetric setting, and 5 of them used it only for urgent notifications.

6 Discussion

6.1 Desirable Characteristics (Q1)

Not surprisingly, perception of design flexibility and low effort are the main factors in participants' choices.

Design space accessed and flexibility afforded by tool framework impacts users' perception of *Design Control*. The perceived size of the design space is larger for *Block*. Also, *Block* only provides building blocks for designing vibrations, and thus affords a more flexible structure compared to *Filter* and *Choice*. According to the rankings, *Filter* provides reasonable design control (not significantly lower than *Block* and *Choice* has the least design control.

Holistic control over stimuli and visibility of design alternatives can reduce the perception of *Effort*. On average, participants took much less time with *Choice* and *Filter* compared to *Block*. Also, post-questionnaire comments from participants indicate that they perceived *Filter* and *Choice* faster and easier than *Block*. Control granularity and visibility of design alternatives appear to contribute to perceived effort; these parameters were similar for *Choice* and *Filter* but different for *Block*.

***Preference* is a function of the perceived *Design Control*, *Effort*, and *Fun*.** *Choice* customization, which is the most common tool for customizing sound and visual effects in consumer devices, was the least preferred option in our study as it provides minimal sense of control and flexibility. The participants found *Block* time-consuming but *Filter* provided enough design control (not significantly different from *Block*) and required little effort. Thus, it was preferred the most. Also, many found its perceptual structure of the design space intuitive and convenient. Also, we hypothesize that a low ratio of perceptual to actual size of the design space could cause disappointment, since many efforts could eventually feel similar. In *Filter*, these two sizes were very close (ratio$\sim$1) compared to *Block*.

Some participants described *Block* as fun, suitable for when they are in a good mood; i.e. gamelike. *Block*'s "Fun" may arise from a sense of discovery due to its less structured design alternatives.

Finally, we note that tools such as the iPhone tapping tool provide very little structure for users. Comments suggest that ordinary users (in contrast to designers) prefer some degree of structure and outline to restrict the design space and guide their design. P9 specifically stated that *"It (iPhone tapping tool) is simple, and not so much patterns to choose from"*.

6.2 Value and Outcomes (Q2, Q3)

Do users *want* to customize vibrations? Overall, users registered interest in customizing their notifications and playing with customization tools on their mobile devices (Q2). The majority did not require detailed, fine control and preferred quicker holistic changes with more perceptual impact. Factors that typically impact software customization behavior also appear to hold for haptics, including extent of usage, sense of control and identity, required time, and ease-of-use and comprehension of customization tools. Other factors such as creativity, fun and available sensations could be more specific to customizing stimuli. To further address this question, we need to investigate various everyday scenarios for using vibrations and survey users interest in customizing vibrations in each case.

What do users create or choose? Fully categorizing what people choose when given the opportunity (Q3) will be a major, and context-dependent endeavor. As a start, we found some general trends, such as associating urgency to signal energy and preference for some rhythms which are consistent with prior work [14]. However, the designed vibrations vary not only across individuals but also in some cases across the tools which is very likely due, at least partially, to our lab-based WoZ approach. A longitudinal study with the developed tools can provide a more comprehensive answer to this question.

6.3 Wizard-of-Oz Approach

Following our goal of focusing on customization concepts with the low-fidelity prototypes, our WoZ prototypes and evaluation appeared to elicit natural feedback in most cases. Nonetheless, it is possible that the unrealistic delay between indicating a command and feeling the sensations skewed certain data; specifically, making it difficult for the participants to compare urgency and pleasantness. However, the impact of this on *tool* preference should be minimal. Participant questionnaire responses suggest that they understood and responded to the paradigm for each tool.*"[I prefer] Filter for first time exploring [the] available or default choices...[and] Block for advanced customization"(P20).* Further, this delay should negatively impact the preference for *Block* as it had the greatest delay; but despite this, many rated *Block* as their first or second choices.

7 Conclusion and Future Work

In this work, we examined the desirability and practicality of customizing everyday vibrations by ordinary users. We proposed five parameters that can impact users' perception of customization tools including: 1) size of design space, 2) granularity of control, 3) provided design framework, 4) facilitated parameter(s), and 5) clarity of design alternatives. We used cellphone message notification as an example application and prototyped three concepts varying in these parameters, namely, *Choice*, *Filter* and *Block* customization.

Overall, our participants showed interest in customizing VT effects. According to the results of a WoZ study, all three tools were reasonably usable. The participants preferred *Filter* over both *Choice* (current practice) and *Block* because it provides some degree of design control but requires little design effort. *Block* customization was the most demanding of time and effort but also the most powerful. Despite almost unanimous preference for the *Filter* interface, our results indicate that individuals' weights for design control, effort, and fun of a tool is different. Thus, an effective customization tool needs to incorporate a suite of easy-to-use tools with different design controls and affordances to accommodate diverse customization needs.

We did not conduct controlled studies to examine the effect of each parameter in isolation, since the parameters are not orthogonal and all combinations of them are not practically interesting. Instead, we defined three practical customization tool concepts to capture the variability along those parameters. The proposed parameters were useful in understanding users' opinions of our tools and the iPhone tool. We think the actual size of the design space and flexibility of the design framework impacts perception of design control. Holistic control over stimuli and visibility of design alternative can reduce the perception of effort. Preference is a function of the perceived design control, effort, and fun of the interface.

Ongoing questions are whether our proposed parameters can adequately characterize new customization approaches and their use for other scenarios as well as users' reactions to them; if there is an optimal subset of the parameters for characterizing the tools, and even a single optimal set of parameter values. These merit further study; however, we predict the last will be unproductive. Instead, we encourage tool designers to consider variations of their tools along these parameters to find the best parameter combination for their case, and to consider diversity in user preferences.

Our next step is to implement and test our tools on potential target devices (e.g., mobile phones and tablets) to investigate the effect of form factor and direct control over creation of haptic effects. We can then conduct longitudinal studies of customizing vibrations for truly personal use. Moreover, we would like to further investigate the specific *benefits* of customization for users. Does customization increase likeability, learning and usage of the vibrations?

In terms of easing the customization task, we see two immediate opportunities. The first is to use filters for stylizing or branding haptic effects, an approach used extensively in photo editing software and preferred by our participants. What properties do users want to change (e.g., emotion, sensation, or physical properties)? How much does it depend on the design case? How can one design an emotion or sensation filter? The second is to gamify design. Some participants thought using *Block* was fun. We do not know of any haptic design games; these could increase interest in haptics and lead to crowd-sourced designs.

At minimum, intuitive end-user tools will allow professional designers to employ participatory practices. More inclusive tools and processes will expose users' criteria and desires for haptic effects, which is a significant current challenge in professional haptic design.

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