Designing a Vibrotactile Language for a Wearable Vest

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Abstract. We designed a wearable vest that houses a set of actuators to be placed at specific points on the body. We developed vibrotactile patterns to induce five sensation types: (1) Calming, (2 patterns, Up and Down back) (2) Feel Good (4 patterns in different directions around the waist), (3) Activating (2 patterns, Tarzan and Shiver, on top front of body and then down the back as well for Shiver), (4) Navigation (2 patterns, Turn Left and Turn Right, prompting on back then opposite side front waist) for full body turning and (5) Warning, (1 pattern on solar plexus) to slow down or stop the wearers. We made an overlap between the pulses, which were of longer durations than the short burst saltation pulses designed to induce muscle movement. Our participants responded well to the Calming and Feel Good patterns, but reported mixed responses to Activation, Navigation and Warning patterns.

Keywords: Wearable technology · Vibrotactile patterns · Calming effects

1 Introduction

In this paper, we investigate responses to a series of vibrotactile patterns designed for a wearable vest. The patterns are designed to provide sensations at a specific series of points on the body in order to energise, calm, feel-good, warn and/or assist with whole body navigation (turning the body) for the wearers.

We examine novel placement and patterns for vibrotactile actuators on the body housed in the wearable vest. In collaborating with a kinesiologist studying neurophysiology to design the intended affects, the placement and patterns were informed by, but unusual to much work in the area. We designed flowing style motions on the body with the vibrotactile pulses to emulate sensations such as stroking up or down the back to relax a person— 'there, there, it's okay'—and patterns of activation—emulating thumping the chest to bring the energy levels up, or vibrating with a series of fast over-laying patterns at the solar plexus to warn or stop the person if they are in danger. We work with activation, calming, feel good and warning patterns at sympathetic meridian points and junctions in the body. We also work with turning and guiding the whole body. The vibrotactile sensations emulate the types of touch patterns a kinesiologist-neurophysiologist uses to slow down or activate areas in the body.

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Fig. 1. Participants 'playing' with the sensations at the wall, a swipe on the wall is felt in the same direction on the body, up, down or sideways left to right, or right to left.

In order to have an interactive environment for the vest wearer, we built an interactive vibrotactile work named The Humming Wall: a 12 m long by 3.5 m wide and 2.7 m high wall for interacting with the vest and general public use. While this aspect of the interaction is not the focus of this paper and will be reported elsewhere, it is important to note that the wall sends and receives vibrotactile and physiological interactions with and to the vibrotactile wearable vest. This means vest wearers can see, hear and feel their own heartbeat and breath in the vibroacoustics of the wall. In addition, participants can swipe and knock on The Humming Wall and the vest wearer is effectively swiped and knocked upon (triggering the patterns we designed for in the vest). Stroking up or down the wall produces stroking up and down the vest. Swiping sideways produces sensations around the waist in the same direction as the swipe (see Fig. 1 for an example).

2 Related Background

Smart wearables and fitness gadgets are big right now. The fitness market place is rife with small wearable technologies that track and respond to physiological data. Core to these advances is the bringing together of interdisciplinary teams from diverse technology fields of software design, electronic design and manufacture and healthcare. Wearable technologies adding stress level readings and integrated fall detection and alarm function which automatically alert designated contacts that the user is in need of assistance are also coming onto the market, expanding the market beyond fitness to include assistive technologies.

Research on vibrotactile interfaces for disabled users has largely focused on visually-impaired users to assist interaction with others and the environment: to enhance navigation [1], to interact with nearby objects [2], to present graphical information non-visually [6], to enrich interpersonal communication [8], to play videogames [20] or to teach choreographed dance [3]. Other research addresses problems with hearing impairments, using vibrotactile interfaces to translate sounds (music, speech or environmental noises) into physical vibrations [4, 5]. For example, the Music-touch Shoes, embedded with a vibrotactile interface, were used by dancers with hearing impairments to feel the rhythm and tempo of music through variable stimulation signals in the soles of the shoes [5].

Vibrotactile information can act as a supportive function to motivate users' actions. Spelmezan et al. [6] demonstrated that 10 patterns developed as a tactile language could assist athletes to improve their motor skills in snowboarding. Further, work by Rosenthal et al. uses a Vibrotactile Belt for teaching choreographed dance through vibrotactile cues [3]. Nummenmaa et al. asked people to draw-map where they thought emotions such as anger, fear, joy, happiness, sadness etc. resided in the body [7]. Similarly, Arafsha et al., asked participants to draw where love, joy, surprise, anger, sorrow, fear resided and included 3 types of haptic feedback with vibration, rhythm and warmth as enhancers [8], building on a long history of 'hugging' jackets and toys—enhancing feel good and comforter variations.

There are many factors to be considered with designing for the body, for long term wear, for comfort, for accuracy, to support movement, for a variety of body shapes and sizes etc. Placement location, number and types of tactors, arrangement, frequency, spacing, tempo, sequencing, connection methods and duration are all important factors when designing a wearable vibrotactile 'outfit' [9, 10]. Karuei et al. identified the wrists and spine as consistently most sensitive sites and found movement to be an impacting factor in decreasing detection rate [10] where Morrison et al. found doing other activities reduced detection performance of vibrotactile stimuli [11]. Much vibrotactile research works with ensuring each tactor can be individually felt and ensuring distance between vibrators and pauses between vibrations are correct to ensure this (see for example [12–14]), in particular to elicit the effect of movement. While these and other works motivated and informed the work we do here, our priority is also to calm people, to work with and adjust their emotional and physical states, to activate-motivate them to action and to gently guide the participants' navigation.

3 System: The Vest and the Patterns

The Vest. The vest is made of two layers—the inner layer comprises an adjustable harness and the outer a padded stretchable vest. The inner adjustable harness, is a 'one-size-fits all' that holds 32 actuators, moveable in order to ensure they are located on the correct location points for each different shaped body (Fig. 2a, b). The outer snuggly-fitting vest is a padded layered stretchable vest, made in 3 adjustable sizes and designed to keep the eccentric rotating mass actuators tightly placed against the bowed-curved areas of the body, such as the lower back and chest, to ensure the vibrations are evenly felt in all areas. The lower harness fits around the legs, ensuring that the harness will stay pulled down holding the actuators in place as the participants move about.

We integrated Zephyr's BioHarness 3 [15] into the harness and vest system to read the heartbeat and breath rate of the wearer in real-time. Two custom-made electronic boards drive the wearable system. One board acts for communication and the other powers and controls the actuators.

The outer shell–made in 3 adjustable sizes—is a padded layered stretchable vest designed to keep the actuators tightly placed against the bowed-curved areas of the body, such as the lower back and chest, to ensure the vibrations are evenly felt in all

Fig. 2. a. Inner Layer Adjustable Harness Front. b. Inner Layer Harness Back. Blue dots indicate actuator positions for up and down patterns. c. Outer padded stretchable vest and skirt

areas. We offered an adjustable skirt-apron for the sake of modesty and/or aesthetics, particularly for those wearing dresses (Fig. 2c).

The Vibrotactile Patterns. We collaborated on positioning of the actuators, rhythms of pulses and patterns and the combinations with an experienced Kinesiologist training in Neurophysiology and working with responsive points and zones of the body. We combined the different pulses, overlaps, rhythms and patterns to emulate the hands on work that a Kinesiologist does in activating or calming down inactive or overactive sequential points of the body. Kinesiology works with an understanding of the body as a set of rhizome like structures stemming from functioning communication tracks between the larger organs—the meridian system. The touch can be calming but is more often probing, even jabbing in a sequence of jiggle, pause, jiggle series (similar to saltation effect) but set up in a longer series of rhythms, with the body then given time to process and assimilate before the next points are accessed to be activated and/or calmed. The patterns we developed fall into five categories: (1) Calming and/or Feel Good (Back and Waist); (2) Feel Good (Waist); (3) Activating (Front and Back); (4) Navigation (whole body) and (5) Warning (Mid front). The actuators operate in overlapping patterns in order to provide various haptic synesthesia sensations such as sense of movement up down or around the body, a body shiver, states of activation and/or calming as well as providing navigational whole body-turning cues. For example, actions such as (1) calming-comforting; stroking the back to calm or comfort a person, (see Fig. 2b), (2) guidance-navigation; placing hands on nape of back and shoulder and turning at the hip as if to support and guide an elder and/or (3) warning; stopping the body with pulses to the solar plexus—acting as if a warning. Activation patterns found mostly on the front of the body include Shiver and Tarzan sequences with for example, pulses in the top two actuators under the collarbones in rapid succession, then for a longer duration (appearing stronger) pulses to the midpoint actuator emulating 'The Tarzan Effect'—Tarzan thumps his chest to raise his energy levels before action. Shiver includes shorter version of these same front patterns followed by patterns up and down the back (a whole body shiver-shudder, akin to what we might experience while saying 'somebody walked over my grave'.

See Fig. 3 for positioning of actuators on the body and indication of the naming scheme for each actuator and Table 1 for information on a selection of the patterns. Table 1 includes the sensation category, location on the body, the pattern structure, total duration of the overall pattern, individual activation length (act.), overlap of

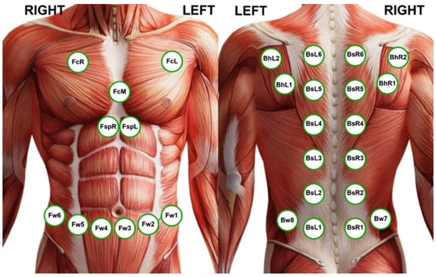

Fig. 3. Actuator naming scheme, e.g. actuators at front waist: Fw1 FrontWaistActuator1st, (actuators numbered 1-6, from left to right); then continues to back waist: Bw7, position BackWaistActuator 7th at right side. Other codes include: FcR: FrontChestRight (&Left&Middle), BsL1: BackSpineLeft1st (1-6), FspR: FrontSolarplexusRight (&Left), BhR1: BackHandRight1st (of 2&Left repeat).

Table 1. Pattern structure details

	Up	Down	Shiver	Tarzan	Turn Left	Stop
sensat.	calming	calming	activating	activating	navigation	alert
location	back	back	front, back	front	back, waist	front
len.	1225	1225	1200	2300	2500	900
act.	350	350	500	500	500	900
overl.	175	175	400	200	0	0
ampl.	3500	3500	4000	4000	4000	4000
step 0	BsL1, BsR1	BsL6, BsR6	FcM	FcL, FcR	Bw7	FspL, FspR
1	BsL2, BsR2	BsL5, BsR5	FcL, FcR	FcL, FcR	BhR1, BhR2	
2	BsL3, BsR3	BsL4, BsR4	BhL2, BhR2	FcL, FcR	Fw3, Fw2	
3	BsL4, BsR4	BsL3, BsR3	BsL5, BsR5	FcL, FcR	Fw2, Fw1	
4	BsL5, BsR5	BsL2, BsR2	BsL4, BsR4		Fw1, BW8	
5	BsL6, BsR6	BsL1, BsR1	BsL3, BsR3	FcM		
6			BsL2, BsR2			
7			FcM	Fw6, Bw7		Fw5, Fw2
8				Fw5,Fw4		Fw4, Fw3
9			FcM			

consecutive activations (overl.), amplitude of activation (ampl.), and the activators as they were activated with each step in sequence. In this first trial, the duration and amplitude were replicated throughout the whole pattern.

In the patterns we deliberately overlap transitions between 0–400 ms (with most between 200–350 ms) and vary duration from 175–500 ms to enable a smooth flowing sensation between pulses, rather than working with the short bursts of 100 ms followed by repetitions of 50 ms that are used to produce saltation effects. Saltation, works as a perceptual illusion, where rapid vibrotactile pulses delivered first to one location and then to another on the skin produces the sensation of a virtual vibration between the two vibrators [12]. Saltation is used to motivate particular movements: flexion, extension, abduction, adduction and rotation. For example, to flex and extend the elbow [16], three vibration motors were placed on an arm band between 6.4 to 7.6 cm apart [12] on the bicep muscle above the elbow joint near the muscle/joint/body part involved in the fundamental movement [13]. In that instant, the pattern of vibration using the saltation illusion, pulsed three motors located in line to render directional information on the skin. The standard burst duration of 100 ms was used with 50 ms inter-burst interval for repetitions, considered optimal to elicit saltation [12] and subsequently used successfully [13, 14]. For the pattern each vibration cue is repeated in sequence as recommended [13] for improved user perception.

For this particular case study, identification of actual location and/or flexion, extension, abduction, adduction and rotation of muscles is not the aim of the work. Rather, emulating natural-enough touch is the effect we are working towards. To do this we have overlaps between the vibrators, so e.g. BackSideLeft6 vibrator is still operating when BackSideLeft5 actuator kicks in. As the pulsations move up both sides of the spine this is repeated at the same time on the right side of the spine at BackSideRight6 (BsR6) and BsR65. The overlap where both vibrators are operating at the same time is 175 ms. This continues throughout the pattern with a 175 ms overlap between BackSideLeft4 (&BsR4), BackSideLeft3 (&BsR3), BackSideLeft2 (&BsR3) and BackSideLeft1 (&BsR1). The duration of the individual activation length (act.), overlap of consecutive activations (overl.) and amplitude of activation (ampl.) are then played the same for all steps on the back Up and Down patterns. We developed this range of vibrotactile patterns in the vest to induce five sensation types in situ: (1) Calming, (2 patterns, Up and Down back) (2) Feel Good (4 patterns in different combinations and directions around waist), (3) Activating (2 patterns, Shiver and Tarzan), (4) Navigation prompts (2 patterns, Turn Left and Turn Right on back and opposite front waist) for full body turning and (5) Information-Warning, (1 pattern on solar plexus) to slow down or stop. In addition, the vibroacoustic *Humming Wall* reacts to human touch—knock, swipe etc.—and conveys these both at the wall and to the vest and responds to and displays the heartbeat and breath rate of the vest wearer.

4 The Trial: Procedure

We ran trials for 5 weeks at Utzon Park, Aalborg. From our preliminary tests, we found it worked better to have pairs experience the wall-vest interactions, so we asked participants to invite a friend, colleague, family-member or loved one rather than pair with an unknown researcher. The duration of the trials varied from between 1.5 to 4 h per pair, averaging 2.5 h. We ran the trials in four phases: (1) *Fitting*, 15-35 min; (2) *Training with vest*, participants walked up and down in the park (1 researcher guided and 1 videoed) while being introduced to the ten vibration patterns for 3 times for each pattern (median length of 10 s for all three together). Participants were asked to *talk aloud* their responses to the sensations. After this, participants and researchers stopped and participants articulated their responses to a repeat of each individual pattern, walking slowly while experiencing and discussing the ones related to motion, 10–15 min; (3) *Interaction*: We sectioned the wall into zones of discrete either (1) calming or (2) energising activities. Participants and their pair interacted with 5 zones at *The Humming Wall,* with a repeat visit to each of the two physiology zones (calming)—one displaying heartbeat, the other breath rate, making 7 stops in all. The other three zones responded to gestures (energising). The participants were instructed on what to do in each zone (e.g., knock on these 3 panels; swipe these 3 panels; sit & breathe). All knocks and swipes on the wall were relayed to and felt in the vest, 20–90 min; (4) *Evaluation*, 15–40 min.

The Participants. We enlisted 39 volunteers with ages ranging from 12 to 65 years (average age 39), 20 females and 19 males. 19 people participated in mixed gender groups, 11 in female/female and 9 in male/male groups (uneven numbers are due to only one participant from one of the pairs wearing a vest). Most people paired with close or good friends (11), their partners (10), colleagues (10), family members (5), or social friends or acquaintances (3). 22 self-reported basic or average IT skills with 17 advanced or above, with 28 spending on average more than 20 h on a computer each week and 12 enjoyed playing a musical instrument regularly. 31 had tertiary level qualifications and 14 were knowledgeable about wearable technology.

Data Collection. We gathered data using quantitative and qualitative methods. Before the trial, the participants filled in informed consent forms and a demographic questionnaire asking about fitness levels; experience levels with IT, vibrotactile technology, embodied interaction, large public displays and playing musical instruments. Activity was logged for each participant from the haptics in the vest; the BioHarness: capturing heartbeat and breath; and actions on the wall: knocking and swiping, frequency, segment and direction. Each pair of participants was accompanied throughout the trial by two researchers, one guiding and one videoing. On return from the field, participants completed shortened adapted versions of questions from MEC Spatial Presence Questionnaire (MEC-SPQ) [17], Flow State Scale (FSS) [18] and Intrinsic Motivation Inventory (IMI) [19] to gauge reactions to the sensations in the vest and the interaction with *The Humming Wall*. The questionnaires comprised 21 X 5-level Likert-type items (from completely disagree to completely agree) to analyse and cross-check users' perceptions. The overall experience was measured through 10 semantic differential scale items with 5 levels (see Fig. 4). Lastly, each participant described their experience, highlighting aspects in semi-structured recorded interviews.

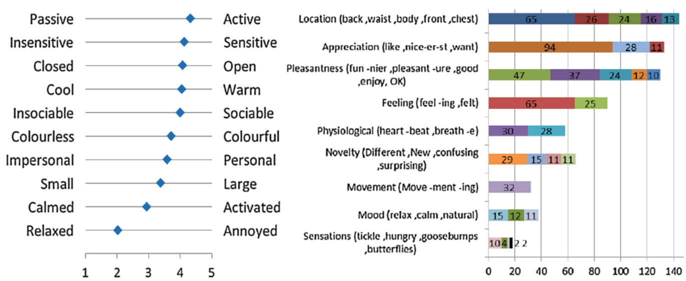

Fig. 4. Semantic differential values on overall experience (left), Word counts from debrief interviews by categories with terms mentioned in parentheses (right).

Data Processing and Analysis. Data post-processing tasks included transcribing user interviews and translating them into English for further analysis. We transcribed the talk aloud responses of the participants to each vibration and coded them numerically. From the English translations of the transcribed Danish debrief interviews we obtained word frequencies and included descriptive adjectives and nouns that received more than 10 mentions and grouped them into topics summarised in Fig. 4, right. We analysed all data sources across the demographic variables to ensure we tested for impact from gender, age, fitness levels and/or prior experience with IT, vibrotactile technology, embodied interaction, large public displays and playing musical instruments, etc. We also analysed logging of activity at the wall, reported elsewhere.

5 Results

In this section we report on findings from Questionnaires, System logging, Video footage and Semi-structured interviews. We concentrate on responses to patterns in the vest. Wall, physiological data and other interactions will be reported elsewhere.

The participants joined in the spirit of the trials and were generally interested in uncovering what the vest patterns might mean. Questionnaire results revealed users found it pleasant to complete the different activities, they concentrated, understood requirements, were active and most felt that they lost track of time during the trial.

Participants were asked how they experienced the vest (and the wall) during the experiment (see Fig. 4, left). They reported to be relaxed, even though they reported to be active as well. Further, users felt that it to be a personal, sensitive, open, warm and colourful experience. Participants exercising 2 or more times per week, found doing the tasks more pleasant, and reported warmer and more relaxed experiences than those exercising less. Those less knowledgeable with vibrotactile technology enjoyed learning how to do the tasks suggested by the sensation more, had a more personal but less active experience than the tech-savvy ones.

The semi-structured interviews used terms from the training phase and included questions such as *'How did you find: the sensations in the vest?' 'Did you prefer some patterns to others?'* in order to get participants expanding on their specific experiences. The most common words offered by participants in these interviews are depicted in Fig. 4, right. We received a variety of comments with many participants describing the interactions as fun, pleasurable, unusual or new and different. The most common expressed terms on enjoyment were: Fun, Like, Want, Pleasant-pleasure and Enjoy. People referred often to *feeling* and identified parts of the body: Back, Waist Front, Chest and Body per se as well as to Heart or heartbeat and Breath. They also referred often to movement, and/or Different-Confusing-New–Surprise and/or Calm-Relaxing-Natural (see Fig. 4, right).

When responding to the vest related questions, participants felt it was possible to be active in the surroundings, important to do well and did not feel much discomfort associated with the vibrations in the vest. In general users stated that they were concentrating on the sensations in the vest, and interpreted some sensations to hold greater meaning than others.

Many immediately found the experience enjoyable: '*Funny - different –a new experience'*. Others took time to adjust: '*In the beginning it was a new feeling, and it was stressful … because it was a new experience in my life. Later I got used to it*'.

We used the numerically coded (1, 0, -1) talk aloud responses to the 10 patterns in a non-parametric Friedman test, which yielded a significant difference between patterns (see Fig. 5 for an overview of the averages). Post hoc comparisons showed that Up, Down, WaistLeftToRight and WaistRightToLeft all were significantly more positively evaluated than all other patterns (with the exception of WaistLeftToRight not being significantly different from TurnLeft and MidFrontToBack). Tarzan and Stop were evaluated more negatively—significantly worse than all other patterns apart from non-significant differences between Stop and both TurnRight and Shiver.

We asked '*Do the patterns suggest anything to you?*' Responses included sensations such as tickling, butterflies, hunger or goose bumps, for example_ '*some feeling was like butterflies in the stomach.'* And *'The tickling on the side… gave me goose bumps from the outside—like you didn't have the sensation but got the goose bumps anyway'* or—'*Solar plexus, not so bad once got used to it—at first didn't like it'… 'it could be a warning of don't do that'*.

For some, the vibrations on the front of the body (the activating *Tarzan* and *Shiver* or Warning *Stop* patterns*)* were the most testing: '*Front—it was not uncomfortable but not as pleasant—the ones on the back are more natural so the front are not as natural'*. For others: '*The feeling in the chest was best, feel it better also at lower back—very nice',* while many more said similar about e.g. the back and waist. *'Up and down the back I liked the most. It is hard to tell, none were unpleasant.'*

Others differentiated between the up and down spine, finding up more activating *'swipe down on spine more calming, upwards more alert, enjoyable—stood me up'* and '*was like lifting me up with the up swipe, down swipe was just pleasant'*.

Sensations occurring in more than just one area of the body at the same time often confused people.

Some participants likened the sensation to a real touch: '*Putting up the same emotion as touch—bringing out the same sense of well-being or happiness as when somebody touches or pats or hugs you… the hug* [Shiver] *was very surprising'*. Many were more comfortable with familiar sensations: '*I like the one on my spine the most… it resembles what people do with the people they know, when they stroke them on the back or something. So I think it was the most comfortable one.'*

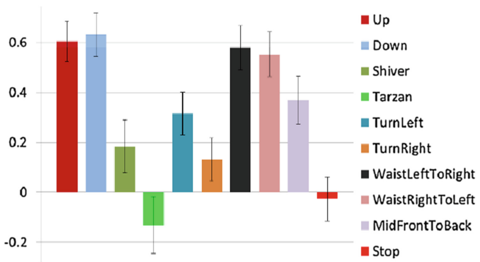

Fig. 5. Means of coded responses to the vibration patterns with error bars (std. error of mean)

6 Findings and Discussion

In this section we discuss findings from testing the different vibrotactile patterns. Some sensations made more sense than others, and this was confirmed in the video logging and in semi-structured interviews. We found people responded more positively to Up, Down, on the waist right to left and for waist left to right patterns, (calming patterns) than to e.g. Shiver, Tarzan (activating) or Turn Left and Stop (guiding). Still the reactions were mixed—some requested more activating (the chest—Tarzan or Shiver), while most preferred the calming sensations (waist and back). These were considered more comfortable, similar to what it feels like to be stroked by another. Vibrotactile technology experts had more active yet more relaxed experiences, while those less familiar had a more personal experience. While many were uncertain how to 'name the patterns or the experience', for most this was an activating-relaxing enjoyable experience. We would not expect that the activation and warning patterns would be considered as enjoyable as the calming and feel-good ones. They are designed to act to energise or force attention and while some participants reported enjoying these, we need to refine and investigate further to clarify impacting factors.

Language. In the training and interview discussions, many had difficulty when attempting to describe an unfamiliar new pattern. We found most struggled to find words to describe the sensations and convey their impressions: '*haven't felt before, yes single vibrations from mobile, but not all over body and flowing, so not sure how to describe what it does… is new'*. The terminology is not at hand for people to be able to easily describe their experiences [21]. For this study, we referred to the sensations as patterns but did not identify each one to the participants in order to avoid influencing their perception-experience. An existing language set is the H-E-Vocabulary, which uses terms such as 'Prickly' for 16 Hz sensations and 'Tingling' for 250 Hz [20], which could act as foundational work to expand upon with input from our own participants' responses.

Therapeutic. Several participants found the vest to be therapeutic or nurturing vibrating on previously sore parts of their body. '*I had an operation top of my waist, so at first it was 'ooh!' I am not used to being touched there any more. Then I got used to it and after a while it felt very safe and good to be touched there again. It was really helpful'*. For others their responsiveness increased: '*Surprised how sensitive I became, this increased during trial. More body got used to listening to the sensation, better it picked up on them.*' '*Start to feel, afterwards, become part of you—sensation quickly become natural, and it kept my mind occupied, when I got more physical'*. Such strong responses to the sensations were unexpected but clearly point to potential for rehabilitation and assistive patterns to improve quality of life.

Activating and full body navigation was less clear to many of our participants. Where more than one location vibrated at the same time as another, participants found difficulty with which vibration to pay attention to. Other studies have found similar outcomes [10, 13, 14, 20], and while we had success with several patterns using multiple locations, the patterns needed to run in sequential order, not at the same time. Interspersing saltation with longer duration and overlap patterns might assist with instigating full body turning for navigation patterns. It remains high priority, to be gentle to bodies (avoiding probing sensations, except for the warning pattern) given the potentially diverse audience—fit and fragile—that this work could be useful for.

7 Conclusion and Future Work

Our participants responded significantly more positively the Calming and Feel Good patterns, but reported mixed responses to Activation, Navigation and Warning patterns. Overall the participants were immersed and very positive: that the patterns felt good, were likened to real touch and the experience was fun and personal is reassuring for this first pass at emulating natural touch sensations with vibrotactile patterns. A key element missing in exploring tactile experience is an expansive vocabulary to adequately describe the nuances between the vibrotactile sensations and the patterns themselves. To address this in future versions, the training phase would familiarise participants with revised pattern names and include a set of terms and elements for consideration. We will add sensate terms identified by participants —hungry, ants, goosebumps, butterflies, tickling, and/or crawling as well as specifying location on parts of body, types of movement and mood-determiners (relaxed, activated, calm, overwhelmed, agitated etc.) as initial steps. For the activation, navigation and confusing or less comfortable patterns, we will investigate longer repeating pattern sequences, interspersing saltation and working with one body location at a time. We have a modified version of the revised patterns and vest ready to begin comparative impact factor testing. We contribute with evidence on the effectiveness of Calming and Feel Good patterns replicating natural touch and outline future work required for activating, navigation and warning patterns while contributing to building an expansive vocabulary for articulating vibrotactile sensations and patterns.

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References

1. Ghiani, G., Leporini, B., Paternò, F.: Vibrotactile feedback to aid blind users of mobile guides. J. Vis. Lang. Comput. **20**, 305–317 (2009)
2. Bahram, S., Chakraborty, A., Ravindran, S., Amant, R.S.: Intelligent Interaction in Accessible Applications. A Multimodal End-2-End Approach to Accessible Computing, pp. 93–117. Springer, London (2013)
3. Rosenthal, J., Edwards, N., Villanueva, D., Krishna, S., McDaniel, T., Panchanathan, S.: Design, implementation, and case study of a pragmatic vibrotactile belt. IEEE Trans. Instrum. Meas. **60**, 114–125 (2011)
4. Nanayakkara, S., Taylor, E., Wyse, L., Ong, S.H.: An enhanced musical experience for the deaf: design and evaluation of a music display and a haptic chair. In: Proceedings of the CHI 2009, pp. 337–346. ACM (2009)

5. Yao, L., Shi, Y., Chi, H., Ji, X., Ying, F.: Music-touch shoes: vibrotactile interface for hearing impaired dancers. In: Proceedings of the TEI 2010, pp. 275–276. ACM (2010)
6. Spelmezan, D.: A language of tactile motion instructions. Ph.D. thesis (2011)
7. Nummenmaa, L., Glerean, E., Hari, R., Hietanen, J.K.: Bodily maps of emotions. Proc. Natl. Acad. Sci. **111**, 646–651 (2014)
8. Arafsha, F., Alam, K.M., El Saddik, A.: EmoJacket: Consumer centric wearable affective jacket to enhance emotional immersion. In: Proceedings of the IIT 2012, pp. 350–355 (2012)
9. Gemperle, F., Hirsch, T., Goode, A., Pearce, J., Siewiorek, D., Smailigic, A.: Wearable Vibro-tactile Display. Carnegie Mellon University, CMU Wearable Group (2003)
10. Karuei, I., MacLean, K.E., Foley-Fisher, Z., MacKenzie, R., Koch, S., El-Zohairy, M.: Detecting vibrations across the body in mobile contexts. In: Proceedings of the CHI 2011, pp. 3267–3276. ACM (2011)
11. Morrison, A., Knudsen, L., Andersen, H.J.: Urban vibrations: Sensitivities in the field with a broad demographic. In: Proceedings of the ISWC 2012, pp. 76–79. IEEE (2012)
12. Geldard, F.A., Sherrick, C.E.: The cutaneous“ rabbit”: a perceptual illusion. Science **178**, 178–179 (1972)
13. McDaniel, T., Villanueva, D., Krishna, S., Panchanathan, S.: MOVeMENT: A framework for systematically mapping vibrotactile stimulations to fundamental body movements. In: Proceedings of the HAVE 2010, pp. 1–6. IEEE (2010)
14. Spelmezan, D., Jacobs, M., Hilgers, A., Borchers, J.: Tactile motion instructions for physical activities. In: Proceedings of the CHI 2009, pp. 2243–2252. ACM (2009)
15. Zephyr. http://www.zephyr.com
16. Manresa-Yee, C., Morrison, A., Larsen, J.V., Varona, J.: A vibrotactile interface to motivate movement for children with severe to profound disabilities. In: INTERACCION 2014. ACM (2014)
17. Vorderer, P., Wirth, W., Gouveia, F.R., Biocca, F., Saari, T., Jäncke, F., Böcking, S., Schramm, H., Gysbers, A., Hartmann, T., others: MEC spatial presence questionnaire (MEC-SPQ): Short documentation and instructions for application. Rep. Eur. Community Proj. Presence MEC IST-2001-37661. 3 (2004)
18. Jackson, S.A., Marsh, H.W.: Others: Development and validation of a scale to measure optimal experience: The flow state scale. J. Sport Exerc. Psychol. **18**, 17–35 (1996)
19. Deci, E.L., Ryan, R.M.: The“ what” and“ why” of goal pursuits: Human needs and the self-determination of behavior. Psychol. Inq. **11**, 227–268 (2000)
20. Obrist, M., Seah, S.A., Subramanian, S.: Talking about tactile experiences. In: Proceedings of the CHI 2013, pp. 1659–1668. ACM (2013)
21. Moussette, C.: Simple haptics: Sketching perspectives for the design of haptic interactions (2012). http://www.diva-portal.org/smash/record.jsf?pid=diva2:558987