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Morrison, Ann; Knudsen, L.; Andersen, Hans Jørgen

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Urban Vibrations: Sensitivities in the Field with a Broad Demographic

Ann Morrison, Lars Knudsen, Hans Jørgen Andersen
Department of Architecture, Design and Media Technology
Aalborg University
Aalborg, Denmark
morrison@create.aau.dk, knudsen@create.aau.dk, hja@create.aau.dk

Abstract **- In this paper we describe a field study conducted with a wearable vibration belt where we test to determine the vibration intensity sensitivity ranges on a large diverse group of participants with evenly distributed ages and gender, ranging from seven to 79 years. We test for alterations in sensitivity in the field by introducing an escalating level of distraction in increasingly busy environments. The findings on sensitivity detection range differ from previous lab studies in that we found a decreased detection rate in busy environments. Here we test with a much larger sample and age range, and contribute with the first vibration sensitivity testing outside the lab in an urban public environment.**

Keywords- Urban Vibrations, wearable computing, vibrotactile, sensitivity range, broad demographic, field trials.

I. INTRODUCTION

Recent development with wearable computing, advances in vibration, pervasive and ubiquitous technologies and ways in which information can now be distributed in our surrounding environment is paving the way for new means to support us in our daily life activities. Vibration belts systems have recently been introduced with a variety of applications, such as spatial navigation for combat soldiers and partially sighted people, mobile robot control and dance instruction. These studies demonstrate positive effects using tactile information as an information channel. However, the successful use of tactile information depends on a number of factors such as body location, frequency, waveform, length of signal and age [4]. More recent laboratory studies have shown that body movement can have a varying negative effect on the vibratory sensitivity, depending on the location of the vibrator on the body [5, 7]. Exploring sensitivity in further detail is interesting as this can lead to more optimised proportioned systems and in the end to better user experiences.

Karuei et.al. [5] found that loading the visual sense in the laboratory deteriorates the response time but not the detection rate, while Ferris et.al. [3] discovered the same effect with response time, but that visual tasks decrease recognition rate of spatially or temporally coded vibration patterns. These findings relate to real world situations, but the lack of field studies needs to be addressed, as has been pointed out by the authors of several lab studies, for example van Erp [2] and Kauri et al. [5]. Nielsen et al. [6] found that field evaluations of mobile systems produced more useful information on usability, interaction style and cognitive load problems than laboratory tests. Despite that this is the obvious site for most mobile-type activities the increased time costs account for the relatively fewer mobility field studies. In this paper we investigate tactile sensitivity over a significant age range (from 7 to 79 years), with a relatively equal distribution of gender and age and under field conditions. We vary activity levels in the field to occupy and intentionally distract the test subjects while requiring they detect vibration stimulus from a wearable belt, see Figure 1.

Figure 1. Participants in the field A. 7-year old male B. Female mid 20's C. 79 year old woman.

II. SYSTEM DESCRIPTION

We developed a vibrator belt, fitted with two 310-113 and two 310-105 Precision Microdrives eccentric mass vibrators, sewn into neoprene to produce lower and higher vibration intensity levels. The belt ensured the vibrators were positioned on the participants' bare skin (in order for participants to detect vibrations accurately) at both sides of the navel on the stomach muscles, see Figure 2. The vibrators vibrated for 500ms with intensities between 0.1 to 0.6g (small) and 1.0 to 3.34g (large), measured with a 0.380kg inertial load. A random vibrator was chosen each time a signal was presented, and a random pause between 7.5 to 15 second was used between the vibrations. Participants used one of three buttons to respond to vibrations, with each button representing an increasing level of discomfort. A soft fur button indicated noticing a vibration, a scratchy button represented a small degree of discomfort or irritation and a button with stiff scratching hair represented a higher level of discomfort (see Figure 2, right). The responses (including missed reactions) were time stamped and saved on a microSD card for analysis.

Both the belt and the pouch with feedback buttons used adjustable strap systems to support a wide range of sizes. The pouch attached to the belt via covered electrical wires. This set up allowed the pouch to be worn outside the participants clothing while wearing the belt directly against the skin. The final design (see Figure 1 and 2), was comfortable-enough, adjustable-enough and normal-looking enough to be wearable in public (without arousing undue attention) for the 30-40 minute wearing duration of the trials.

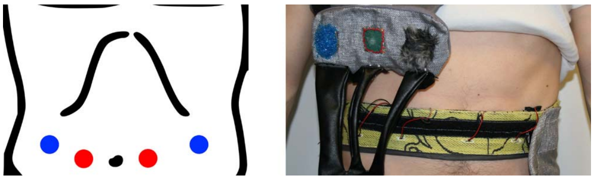

Figure 2. Left. Drawn placement of smaller vibrators on the central dots and larger vibrators on outer. Right. Belt worn underneath clothes, while detachable pouch is worn over clothing.

III. THE FIELD TRIAL

The trial, *Urban Vibrations* was set in downtown Aalborg, Denmark and took one hour per participant. The trial operated in four parts: (1) introduction and training, 15 mins; (2) laboratory setting, 10-15 mins; (3) field setting, 10-15 mins; and (4) evaluation, 15-20 mins. The training, lab trial and evaluation took place in a laboratory setting. In part two, participants could concentrate solely on detecting and responding to vibrations for a set period (30 to 60 vibration signals), generating a benchmark detection rate to compare field trial detection against. The field trial was set in an urban environment with two city squares and walking and traffic streets. The trial was designed to comparatively test field responses against the benchmark results, to detect if and how much distractions had impacted on focus and/or habituated/decreased sensitivity levels to vibrations (30 to 60 vibration signals).

The participants were required to detect and respond to the same random vibrations as in the lab. We designed a set of tasks that would incrementally make more demands on the participants' attention. The trial was contained within a one km area in central Aalborg, Denmark and was designed to be manageable by younger children as well as elderly participants.

There were two types of tasks, continual and event-based. For the two continual tasks participants were required to persistently: 1) respond to each vibration and 2) take photos of things that interested them as they walked. The six event-based tasks related to locations in Aalborg and required the participants either count, estimate, look for information, know or learn Aalborg history, photograph and select one photo. There were two task levels, with three tasks categorised as calm activity, and three categorised as busy. One counting task (count steps, respond to belt vibrations, walk and answer verbal questions) was designed to push the limits of the participants' attention so we could gauge the impact of elevated distraction on sensitivity and detection of vibrations.

A. *The participants*

The trials comprised 42 participants with ages ranging from seven years to 79 years, with an equal distribution of ages and an equal mixed gender ratio. The participants were predominantly Danish with a wide range of ICT and/or mobile phone expertise and educational levels ranging from preschool to PhD. Occupations included craftspeople, accountants, drama students, office workers and researchers.

B. *Data collection*

In the study we gathered data using quantitative and qualitative methods. In training, the participants filled in consent forms and answered a demographic questionnaire. Each button press response to vibrations was logged. In addition, each participant was accompanied throughout by two researchers; one videoing and the other handing out tasks, navigating, reminding the participant of continual activities and observing. On return from the field, each participant was videoed demonstrating using the system. They then described their experience, highlighting aspects that had caught their attention in semi-structured recorded interviews. Additionally, participants completed a two-page questionnaire from Flow, Presence, and Intrinsic Motivation research to gauge reactions to the technology and the experience [1, 8, 9]. We refrained from suggesting how they might use the belt-system and avoided using prompting words to assist them in describing their experience.

IV. RESULTS: QUALITATIVE FINDINGS

In this preliminary analysis, we detail observations, video-analysis, audio recording and self-reporting from demos, interviews and questionnaires.

1) Sensitivity differences in the field. From interviews and while demonstrating how they used the system, participants reported that they experienced less irritating and uncomfortable sensations in the field than in the lab. Many expressed concern, even while walking in the field, that they were sure that they were missing the less-intense vibrations while in motion outside. This result was repeated in the questionnaires, where 75% reported they missed some responses to the vibrations as they were distracted with the environment or tasks. The consensus was that most people found the higher vibrations less noticeable in the field. Those that found some vibrations uncomfortable in the lab reported or even mentioned while walking that they found them less so in the field.

2) Irritated by Interruption and Distraction. Despite the vibrations being unrelated to any particular tasks, 82.5% reported it was important for them to do well with the belt and this was also what we observed. Some also mentioned the vibrations as annoying interruptions, because they prompted a response, while they might be preoccupied with something else. In addition, 70% reported they were distracted, used the term multitasking without prompting, felt they had a lot to do or felt stressed while in the field.

With the more difficult counting task that was designed to push participants' limits, 48% mentioned this task as being harder than the rest. The task required synchronously counting steps, taking photos, responding to the belt and being asked several conversation-type questions by the researchers. Participants responded in several ways. Some simply refused to answer the questions, shaking their head or miming counting. Others responded chattily, then later exclaimed (sometimes several verbal responses later), ‘Oh no I’ve lost count’. Others became visibly agitated, looked crossly at the interlocutor and/or answered tersely. Many mentioned this distraction later in the interview.

3) Establishing a system-of-use. From observations, we noted that most participants generally initiated some kind of easy-enough system-of-use to interact with the belt-system so they did not need to relocate the buttons every time they responded. For many, systems-of-use changed once in the field and tasks, holding a camera and task cards required more mobile and visual dexterity. As time passed, participants often changed how and where they rested their hands and subsequently how they pressed the buttons. Participants often rested their hand or hands on top of or under the belt with fingers positioned within easy reach of the buttons. Some used just one hand, others used two hands, and in this case often rested their hands at each end of the pouch, stretching their fingers out to touch the buttons.

From demonstrations, interviews and questionnaires, we found thirty of the 42 participants reported they worked out a specific way of interacting with the buttons, with others noting they had changed their system-of-use as circumstances changed. Interviews and demonstrations of use confirmed that where a system-of-use was established, this was done for the purpose of avoiding having to continually locate the buttons each time the participants needed to respond to a vibration, as this would require they disengage from what they were doing at the time

4) Comfort, pleasure and future use. Without prompting, 58% reported the belt as comfortable, while 10% found it cumbersome or hot to wear because of the extra weight around the waist. Ninety five percent reported the trial as a positive experience, 84% found the trials active with 70% reporting they felt sensitive in the experience and lost track of time. In addition, 80% said they could imagine using a future version of the product for reasons that largely discussed the non-invasiveness of a system that left the hands, ears and eyes free to use for other tasks and where one could still talk and continue to partake in usual activities (like talking to companions and shopping).

V. Discussion

While our participants ‘complained’ about multi-tasking, we can say from this response that the field trial did replicate a real world experience of use, with many differing levels of distraction. These included dealing with artefacts; looking out for specific buildings or information; navigating other pedestrians in sometimes crowded walking streets; crossing busy roads with bikes, cars, buses, dogs and other pedestrians; taking photos; fitting large buildings in a photo; responding to questions; handling task cards; attempting to be efficient and/or take a worthy photo while detecting and responding to vibrations.

Participants mostly devised their own system-of-use in order to circumvent needing to continually find the buttons (by looking down at the belt, or feeling for buttons) to make each response. They did this to prevent needing to continually interrupt their other activities. Lowered sensitivity in the field and devising a system-of-use to prevent repeatedly needing to look or find the buttons expands on Karuei et al’s [5] lab finding that needing to access visual information slows down actions (participants rest hands close to buttons to prevent needing to look).

The participants’ self reporting on vibrations showed that they expected they missed vibrations in the field that they did not in the laboratory, and that they felt vibrations were less violent, once they were occupied in the urban environment. This shows that tactile systems need to produce signals strong enough for the user to be confident in the system, as they expect a decreased sensitivity in busy or urban environments. Initial analysis of the logged data supports the participants’ assumptions about decreased sensitivity. We find that the decrease in sensitivity is most likely attributed to a preoccupation with aural and visual inputs as well as cognitive workload. This does not directly compare with Karuei et.al [5] lab studies on sensitivity, where they did not find a decreased detection rate when they introduced visual distractions. This may have been due to the intensity of the distraction and/or involvement of the participants. In our case the participants had to handle both visual and aural distractions, as well as several concurrent tasks. This difference in results emphasises the importance of examining real world usage through field trials.

Most participants found the belt-system comfortable-enough to wear, a good outcome for this rough prototype version. From feedback and further research, we can easily see how improvements to dispersing weight with cross straps on the back (such as found with baby carriers and back support) and customizable pouch-type solutions (from small man-bags to hand pieces or forearm attachments) could be implemented. The soft material that moulded easily to the body was generally appreciated.

VI. Conclusion and Future Directions

We contribute with the first field trial testing vibration sensitivity in the field. Our results differ from other lab studies [5] in that by comparison they show a lowering of sensitivity in the field (with distraction) and provides more information on how participants interact with the system while examining a wider age, gender and demographic. We could argue that the decreased detection rate is related to visual and aural distractors and possibly cognitive workload, but future research is needed to examine this further.

We began this study as part of a larger project, entailing wearables and vibration systems as components in a customisable pedestrian navigation system to enhance mobility. While aspects of the larger project focuses on elders, we also examine applications for a younger audience and working with multiple modalities to spread the cognitive load. We needed to know what the vibration sensitivity range was at the lower end of the scale in order to determine what vibrators we would choose as the basis for our design. There is a vast difference in range and cost, making this information vital before embarking on an extensive project.

The results from this study solve our immediate needs for designing and developing for elders and ensure we can design systems for a wider age range with quantifiable measures known at the outset. We also understand that while our system is comfortable-enough it needs improving for longer periods of wear, that it allows for the use of two-hands and reinforces mobility. Therefore, we can continue developing and designing further solutions building on this initial system. The use of for example, the wrist or lower arm, rather than the waist as the vibration sensitivity point is also possible using such a design. Future work includes adding features such as flexible displays, indicative fiber optics, lighter-weight bendable circuitry and cross-over strapping combining baby harness and posture corrector designs for long-term wearability.

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