Grasping the Future: Identifying Potential Applications for Mid-Air Haptics in the Home

Lawrence Van den Bogaert
Mintlab, KU Leuven
Parkstraat 45, box 3605, Leuven, Belgium
lawrence.vandenbogaert@kuleuven.be

David Geerts
Mintlab, KU Leuven
Parkstraat 45, box 3605, Leuven, Belgium
david.geerts@kuleuven.be

Isa Rutten
Mintlab, KU Leuven
Parkstraat 45, box 3605, Leuven, Belgium
isa.rutten@kuleuven.be

ABSTRACT

Mid-air haptics is an emerging technology that can produce a sense of touch in mid-air using ultrasound. While the use of mid-air haptics has a lot of potential in various domains such as automotive, virtual reality or professional healthcare, we suggest that the home is an equally promising domain for such applications. We organized an ideation workshop with 15 participants preceded by a sensitizing phase to identify possible applications for mid-air haptics within the home. From the extensive set of ideas that resulted from this, five themes emerged: guidance, confirmation, information, warning and changing status. As general 'application categories', we propose that they can provide a useful basis for the future design and development of mid-air haptic applications in the home, and possibly also beyond.

CHI'19 Extended Abstracts, May 4-9, 2019, Glasgow, Scotland, UK.

ACM ISBN 978-1-4503-5971-9/19/05.
https://doi.org/10.1145/3290607.3312911

CCS CONCEPTS
• **Human-centered computing~User centered design**
• Hardware~Haptic devices

KEYWORDS
mid-air haptics; ideation; co-design

ACM Reference format:
Lawrence Van den Bogaert, David Geerts, Isa Rutten. 2019. Grasping the Future: Identifying Potential Applications for Mid-Air Haptics in the Home. In CHI Conference on Human Factors in Computing Systems Extended Abstracts (CHI'19 Extended Abstracts), May 4–9, 2019, Glasgow, Scotland, UK. ACM, New York, NY, USA. 6 pages https://doi.org/10.1145/3290607.3312911

1 INTRODUCTION AND RELATED WORK

Our sense of touch serves us on a daily basis in many different situations, contexts and circumstances. At home, we use it from the moment we wake up, trying to hit our buzzing alarm clock, to the moment we turn off the light switch to go to sleep. As the way objects are operated is shifting more and more towards touch-screen or gesture-based interactions, involving our sense of touch will be essential for designing fluent interactions in the future. A promising new technology, capable of generating a sense of touch in mid-air using ultrasound pressure fields, is mid-air haptic feedback [9], which offers new ways of tactile interaction with devices and objects. Several researchers have already demonstrated potential products and applications using mid-air haptic feedback. In an entertainment context, Alexander et al. proposed adding mid-air haptic feedback to mobile television, and suggested that this would increase the appeal of mobile TV broadcasts [2]. Similarly, Ablart et al. studied the effect of integrating mid-air haptics into movie experiences, finding that valence and arousal increases significantly when one-minute movies are augmented with tactile cues [1]. Hwang et al. presented AirPiano as a music playing system in VR, enhanced by mid-air haptics [8].

In the healthcare domain, Kofatias et al. [10] used mid-air haptics in combination with VR for pain distraction with patients. Hung et al. explored the possibilities of employing mid-air haptics to simulate patients' arterial pulse [7]. Other domains for which applications have already been developed are, among others; arts [see e.g. [13]], advertisement [see e.g. [3]] and automotive [see e.g. [6]].

To our knowledge, however, in none of these domains research has been carried out to identify potential applications in a more systematic way. We wanted to fill this gap by exploring potential applications in the home using a structured co-design approach. The result was an extensive set of ideas and, more importantly, the emergence of five underlying themes we call 'application categories'. We propose that these application categories can serve as a point of departure for the future development of applications with mid-air haptics, possibly also in other domains.

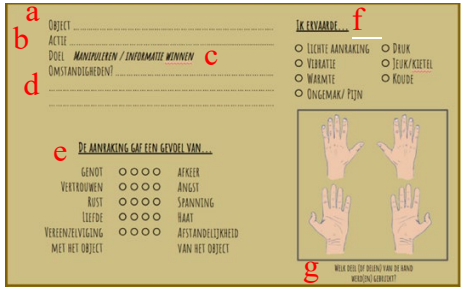

Figure 1: example page of the diary.

For each interaction, we asked participants to record: (a) what object they touched; (b) what the specific action/movement was; (c) what the purpose of the interaction was (manipulate the object or gain information); and (d) whether there were circumstances that hampered the situation (e.g. dirty hands). In addition, we asked about (e) the skin sensations as well as (f) the gut feelings involved in the tactile experience [12]. Finally, for each object there was (g) a drawing of a set of hands, on which participants had to indicate which part(s) were used for this interaction.

2 METHODOLOGY

Following a co-design approach [11], we conducted an ideation workshop with potential end-users, preceded by a sensitizing activity in order to identify possible application areas of mid-air haptics in the household context. Participants were recruited through our research group's website, social media and flyers. Out of 23 registrations, we selected 15 participants. Ages ranged from 21 to 56 (mean 27,4), with 6 men and 9 women. Six participants were students, the rest had a variety of professions. In this paper, participants are coded as follows: [table letter] [participant number] [gender].

Sensitizing Activity

All participants were given a diary two weeks prior to the workshop, in which they were asked to record hand-based household interactions. This sensitizing task had a twofold purpose: (a) to gather relevant insights on what haptic interactions participants encounter and how they experience them; and (b) for the participants themselves to become aware of both the quantity and quality of haptic sensations they experience in their everyday household context. Figure 1 shows an example of a diary page and the questions that were asked.

Ideation Workshop

Using the information gathered from the diaries, we created a board game for facilitating our ideation workshop. This board game served a dual purpose: (a) to create an enjoyable experience for the research participants, and (b) to collect user insights to inform the design process [5]. Through our board game, we gave participants a framework to think of applications for mid-air haptics in a creative, yet structured way. After introducing the purpose of the workshop, all participants could experience mid-air haptic technology. We then divided them in three groups, with each 5 members, to be seated at three separate playing tables. We made sure each group had a balanced mix of gender, age and professional background. The rules to the game were then explained (see table 1), after which participants started ideating solutions for using mid-air haptics in a household context, pitching and discussing them in their group. All discussions and pitches were audio recorded, transcribed and coded in NVivo.

3 RESULTS

In total, 54 solutions were generated. Instead of taking the concrete solutions at face value, we applied thematic analysis to detect underlying ideas and concepts. This resulted in 5 main themes, which we call 'application categories' as they offer a basis for creating concrete applications.

Guidance

Out of 54 solutions, 12 contained the idea of mid-air haptics preceding the actual interaction in the form of 'guidance', either for localization purposes, or as a pedagogical instrument. Haptic guidance for localizing objects was especially mentioned in situations where participants were

Game Rules
Taking turns, players moved around a personal pawn on a 2D house map, divided into different rooms (bedroom, kitchen, bathroom and living room), similar to the game Cluedo™. Once a player entered a room, they had to draw an 'object' card for that room. These were objects typically found in these rooms, e.g. the stove in the kitchen or the alarm clock in the bedroom. In addition, the player had to draw a 'circumstance' card, which added a constraint (e.g. 'your hands are dirty' or 'it is dark in the room'). The combination of cards formed a challenge for the other 4 players, who were divided in pairs and were asked to answer the following question: "how could mid-air haptics provide added value, replace an existing element or change the interaction with this object, given the specific circumstance?". Creation sheets (see figure 2) provided some guidance in doing so. After three minutes of ideation, each pair pitched their idea to the player who drew the combination of object and circumstance. They then decided which idea he found best, allowing the winning duo to proceed on the scoreboard.

Table 1: game rules as explained to participants.

impeded with a visual limitation. For example, one participant (C2f) proposed to integrate a mid-air haptic unit into her front door. When coming home late in the dark, a mid-air haptic signal could then help her to locate the keyhole to unlock the door. She suggested that the closer the user would get to the lock, the stronger the haptic sensation would become. Another participant suggested a similar solution for locating his alarm clock:

"I always find it hard to localize my alarm clock in the morning […] because I am sleep drunk. The device we thought of has a built-in haptic unit, and it 'sends out' a signal [to the hand], and it leads you toward the alarm clock. And as soon as you deviate from the line, you will feel that you're off track." (B5m)

As a pedagogical instrument, mid-air haptic feedback could guide the user's hand during a learning process. In one idea, a mid-air haptic unit was implemented in the sink to guide children's hands when washing them. The participant duo (C2f and C3f) suggested that there is a big difference between an adult explaining what movements have to be made and actually feeling them.

Confirmation

Eleven solutions contained the idea of the user experiencing a sense of confirmation upon interaction with a device. In a passive manner, this confirmation could be provided by a (static) 'forcefield' or 'dome' which indicates to the user that they are within range of a certain object.

"[...] there would be a [mid-air haptic] field and when you put your hands in you feel 'okay my hand is in now' and you can open the fridge [by making a gesture]. You don't want that fridge to just open and close, so there would be like a forcefield and when your hand enters it, you'd know that you can then make the gesture to open it." (A2m)

This specific example shows how a mid-air haptic sensation could confirm, in a passive way, that the user is in the right area to convey input. Just as well, 'confirmation' can be provided more actively, e.g. by holding the hand in front of a control panel and experiencing a haptic sensation that confirms it has registered the user's presence.

Information

Twenty-four solutions included notions of the user acquiring information through the sense of touch. Such information was either 'binary' (on/off, open/closed, ...) or 'continuous' (temperature, battery life, ...). An example of a mid-air haptic application providing binary information came from a participant (A4m) who suggested a thermostat indicating through mid-air haptic feedback which mode it is on. In addition to just the visual cue, a haptic sensation would tell whether the heating system was on automatic or manual mode. Another idea, conveying continuous information, described how the intensity of a haptic sensation coming out of a charging pad might indicate its current charging capacity:

"Nowadays, you have these charging pads on which you can just lay down your cell phone, and it automatically starts charging. These type of charging pads probably have a maximum capacity, which determines how many cell phones you can put on there. Depending on how many devices you put on, the platform would indicate [through a mid-air haptic signal] '[the] capacity is now 100% or 25%'." (C1m)

As the type of information gathered from mid-air haptic sensations can be quite diverse, the

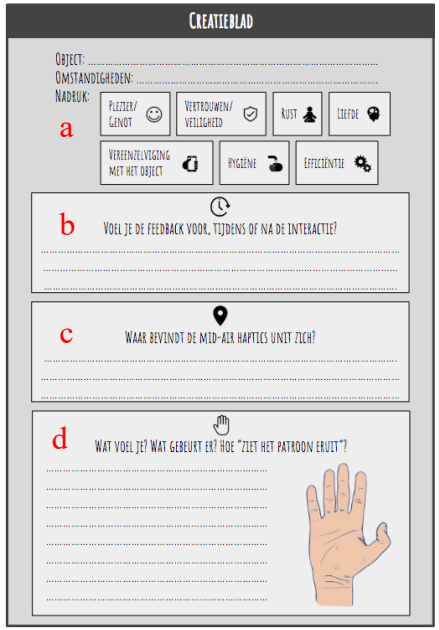

Figure 2: creation sheet provided for ideation.

On these creation sheets, participants were encouraged to think about: (a) the added value or emphasis of their solution (b) the timing of the mid-air haptic feedback (before, during or after the interaction); (c) location of the mid-air haptic unit; and (d) what kind of sensation they would want to feel.

question of which haptic patterns can convey this information showed up. Some participants suggested using the intensity of the mid-air haptic feedback, with low intensity indicating e.g. low temperature or low battery life. Another participant (B3f) suggested using a number of dots projected on the hand to indicate quantity (e.g. five dots meaning full battery capacity and one dot indicating low capacity).

Warning

Twenty-one solutions contained the idea of mid-air haptics as a way to warn users, either actively or passively. From the sensitizing phase, we learned that users are occasionally anxious about certain interactions in their home. For example, opening the dishwasher while it is still running or putting one's hands in a place that might be too hot. A passive forcefield could warn the user that they are about to engage in a possibly dangerous, unpleasant or untimely interaction:

> "This happened to my girlfriend, she was in a rush when cooking and wasn't paying attention – she wanted to take something out of the oven and forgot to put on gloves so she burnt her hands. So when you enter your hands in the oven, we could install a forcefield to remind you that it's hot." (A2m)

Similarly, mid-air haptic feedback could also substitute or complement auditory or visual cues that many household appliances give to indicate something is wrong or act as a timer. Examples are the light of the oven changing when it reaches the desired temperature or the fridge giving a beeping tone when it has been open for too long. Such applications imply a more active way of warning.

Changing Status

Finally, out of 54 solutions, 22 contained aspects of mid-air haptics providing feedback during active operation of an object, to indicate that the status of an object is changing. For example, to turn the lights brighter, the following participant proposed making circular movements with the hand in front of a sensor while receiving 'clicking' sensations:

> "In combination with [mid-air haptic] feedback, we can choose the intensity of the light. So instead of just seeing how the lights get brighter, by spinning our hand we'd feel a click… 1 brighter, 2 brighter, 3 brighter, … […] So we actually 'feel' the light getting brighter or less bright." (A3f)

A similar solution entailed receiving mid-air haptic feedback while turning up the heat to indicate how warm the heating element would eventually get. The participant (B1f) explained how this would be illustrated by a pulsing sensation for which intensity and frequency increased or decreased.

4 CONCLUSION AND FUTURE WORK

As the way objects are operated is shifting more and more towards touch-screen or gesture-based interactions, involving our sense of touch will be essential for designing fluent interactions with these technologies. The many solutions our participants came up with in the ideation workshop, and the underlying themes we derived from them, indicate that there is a lot of potential for technologies using mid-air haptics.

The application categories for mid-air haptics presented in our paper provide a useful basis for

the future development of potential applications of mid-air haptic technology within a household context, and possibly even in other domains. They can provide sensible direction in the design and development of future mid-air haptic applications. Based on these results, we can start to design concrete mid-air haptic applications using co-creation workshops together with end-users, and turn them into working prototypes that will be evaluated with users in realistic contexts.

ACKNOWLEDGMENTS

This work was supported by the SHAKE project, realized in collaboration with imec. Project partners are Verhaert, Nokia Bell, NXP, imec and Mintlab (KU Leuven), with project support from VLAIO (Flanders Innovation and Entrepreneurship).

REFERENCES

[1] Damien Ablart, Carlos Velasco, and Marianna Obrist. 2017. Integrating Mid-Air Haptics into Movie Experiences. In *Proc. of TVX '17*. ACM, 77-84

[2] Jason Alexander, Mark T. Marshall, and Sriram Subramanian. 2011. Adding Haptic Feedback to Mobile TV. *Proc. of CHI '11 Extended Abstracts on Human Factors in Computing Systems*. ACM, 1975-1980

[3] Loic Corenthy, Marcello Giordano, Richard Hayden, Daniel Griffiths, Craig Jeffrey, Hannah Limerick, ... Sriram Subramanian. 2018. Touchless Tactile Displays for Digital Signage: Mid-air Haptics meets Large Screens. *Proc. of CHI'18 Extended Abstracts on Human Factors in Computing Systems*. ACM, Paper D103

[4] Alberto Gallace, and Charles Spence. 2009. The Cognitive and Neural Correlates of Tactile Memory. *Psychological Bulletin* 135, 3 (2009), 380-406

[5] David Geerts, Marije Nouwen, Evert van Beek, Karin Slegers, Fernanda Chocron Miranda, and Lizzy Bleumers. 2018. Using the SGDA Framework to Design and Evaluate Research Games. *Simulation & Gaming* (2018).

[6] Orestis Georgiou, Valerio Biscione, Adam Harwood, Daniel Griffiths, Marcello Giordano, Ben Long, and Tom Carter. 2017. Haptic In-Vehicle Gesture Controls. In *Proc. of AutomotiveUI '17*. ACM, 233-238.

[7] Gary M.Y. Hung, Nigel W. John, Christopher P. Hancock, Derek Gould, and Takayuki Hoshi. 2013. UltraPulse – Simulating a Human Arterial Pulse with Focussed Airborne Ultrasound. *Proc. of IEEE EMBS '13*. IEEE, 2511-2514

[8] Inwook Hwang, Hyungki Son, and Jin R. Kim. (2017). AirPiano: Enhancing Music Playing Experience in Virtual Reality with Mid-Air Haptic Feedback. In *Proc. of IEEE WHC '17*. IEEE, 213-218

[9] Takayuki Iwamoto, Mari Tatezono, Takayuki Hoshi, and Hiroyuki Shinoda. 2008. Airborne Ultrasound Tactile Display. In *SIGGRAPH '08 new tech demos*. ACM, Article 1.

[10] Georgios Karafotias, George Korres, Akiko Teranishi, Wanjoo Park and Mohamad Eid. 2017. Mid-Air Tactile Stimulation for Pain Distraction. *IEEE Transactions on Haptics* 11, 2 (2018), 185-191

[11] Elizabeth Sanders, and Pieter-Jan Stappers. 2012. Convivial Toolbox – Generative Research for The Front End of Design. Amsterdam, The Netherlands: BIS Publishers.

[12] Hendrik N.J. Schifferstein, and Paul Hekkert. 2008. Product Experience. Oxford, UK: Elsevier Ltd. 41-62

[13] Chi Thanh Vi, Damien Ablart, Elia Gatti, Carlos Velasco, and Marianna Obrist. 2017. Not just seeing, but also feeling art: Mid-air haptic experiences integrated in a multisensory art exhibition. *International Journal Human-Computer Studies* 108, 1-14