iasdr 2021 [WITH DESIGN]

PolyU Design
School of Design
The Hong Kong Polytechnic University
5–9 December 2021

# Hand-in-O: Exploring Possibilities of Sensing and Constraining the Gestures with its Frame to Provide Light and Sound Feedback

Lee, Hanbyeol[a]; Kim, Beom[b]; Gim, Seungkyu[c]; Park, Young-Woo[b]*

[a] Graduate School of Creative Design Engineering, UNIST, Ulsan, Korea, Republic of
[b] Department of Design, UNIST, Ulsan, Korea, Republic of
[c] BDCI, Seoul, Korea, Republic of
* The corresponding author e-mail address: ywpark@unist.ac.kr

The invisibility of a physical outline to constrain users within an area for conducting their gesture commands frequently results in making errors, which may further affect the less use of the gesture inputs. In this, despite the advantages of gestural user interface (UI), those were rarely used in our home electronics. This paper explores the possibilities of sensing and constraining the gesture interaction through the design, development, and user study of a research prototype called Hand-in-O. It is a device that constrains users in performing gestures by moving the hands inside of the frame to provide light and sound feedback. Using this, we conducted use experience exploration and a design workshop upon twenty-one participants. From the study, we could obtain categories for suggested usages of Hand-in-O in household contexts. Furthermore, using the frame form's affordance, we found it may attract users' curiosity about performing gesture interactions to control various media in homes.

***Keywords: gesture interaction; frame interface; light; sound control; physical constraints***

## 1 Introduction

The design of everyday interactive things in the commercial market and research field focuses on developing intelligent user interfaces and autonomous and internet of things (IoT) technologies to control electronic items in the home. Due to this, people in the home can now interact with these products by using touch, voice recognition (Porcheron et al., 2018), facial recognition, and gesture interactions. Among them, various gestures are being used to perform actions to give commands through handheld controllers or detect bodily movements with motion sensors. Also, as gestures can be performed through the hand, it holds great potential to be expanded for active use in our homes.

We found a research space to investigate better ways to use our hands for gesture-based interactions to manipulate future everyday interactive products. Previous studies on human-computer interaction (HCI) introduced several examples of gestures for controlling medium focusing on the gaming and medical treatment fields (Aslan et al., 2016). Gestures were applied in visual control using a display; for example, Touchless Circular Menus (Chattopadhyay et al., 2014), Wall-Display Interaction (Wittorf et al., 2016), GesText (Jones et al., 2010), Multiray (Matulic et al., 2018), StrikeAPose (Walter et al., 2013), Vulture (Markussen et al., 2014), and WrisText (Gong et al., 2018), however, those studies reported usability problems when using a display with gestural motions. Also, most examples lacked to provide a guide on a gesture controller and granted users unlimited gestural space (Silhouette Interactions (Chita et al., 2015), Tangible Lights (Sorensen et al., 2015), U-Remo (Ujima et al., 2014)). Meanwhile, Cabreira and Hwang (2016) found that some participants had trouble finding where their hands are detected to use gesture interaction.

Considering the fundamental advantages of gesture inputs that do not require an additional device for control purposes, a physical outline's invisibility to constrain users within an area for conducting their gesture commands often resulted in making errors. These further affected the less use of the gesture-based functions. This issue has led us to focus on our research to explore limiting gestural actions by making the prototype's form a frame shape (Jung and Stolterman, 2012) to help users perform gestures inside the frame's physical outline. Besides, we approached to provide light feedback according to the gestural inputs to investigate the effect of interaction within the frame. For this, we designed and developed a research prototype called Hand-in-O (Figure 1) to explore the potentials of a frame-shaped device for sensing and constraining the gestures with its frame. We also focused on increasing our research prototype's finishing quality to provide a deeper and more immersive experience to the user uses (Odom et al., 2016). Using Hand-in-O, we conducted exploratory studies, including a design workshop to test basic usability and discuss how gestural controllers could be applied in certain situations and contexts in homes.

*Figure 1. Hand-in-O prototype. The perforated space inside the frame is large enough to put both hands in. Light comes from inside the frame, and there is a Leap Motion at the bottom of the frame that can recognize hand gestures.*

## 2 Design and Development of a Research Prototype: Hand-in-O

Our primary focus in designing this artefact was to investigate our design approach's applicability within the context of everyday lives. When designing Hand-in-O, we considered how it could be developed with a gestural area limited by a frame-shaped form. We designed it as a long rectangular frame regarding the recognition range of Leap Motion that can detect different types of gestural inputs properly. In this, users can perform hand gestures inside the frame and receive light feedback according to each gesture. Furthermore, we needed to design a suitable situation where a gesture interface could experiment with Hand-in-O. We set up a music control situation that does not require an additional display. Figure 2 shows the initial gesture interaction and light feedback that we have designed as a default for exploring the sensing and constraining hand gestural inputs with its physical form in the context of music control.


*Figure 2. Gesture interaction and light feedback in the context of music control.* ***Left*** *- The color of light changes when users put their hand to each side in the frame for more than 3 seconds;* ***Right*** *- the song pauses when the user clenches a fist and fast-forwards when the user moves the hand to the right.*

During the design process (Figure 3), we fabricated our research prototype by carefully manufacturing to hide the parting line and joint to accomplish production-level high fidelity, considering the enhancement of clear colour and glossy finish (Figure 4, right).

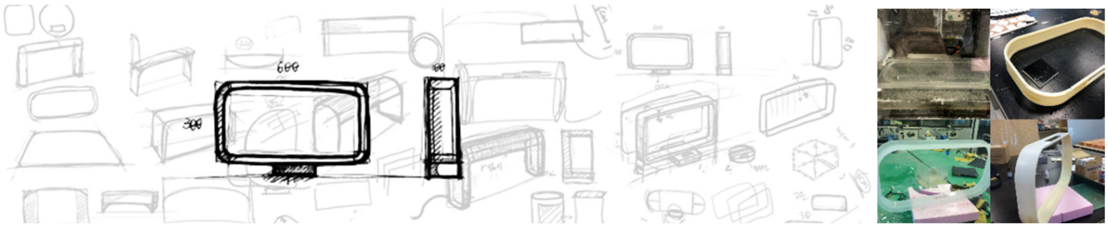


*Figure 3. Design and fabrication process of Hand-in-O prototype.*

In addition, the technology of the prototype and the gestural control was thoroughly designed considering the uncertainty of the context of use. Every design feature is determined to make the prototype naturally fit into its surroundings (Figure 4, left). For instance, a transparent acrylic material was chosen for effective delivery of light feedback, and the shrinking curvilinear line from the outer to the inner part of the frame was intended to induce user hands to be stretched toward the centre of the frame. A round silhouette was applied with the consideration of continuous hand gestural control.

*Figure 4. Hand-in-O in an everyday environment (left and middle).*

## 2.1 Implementation

**Hardware:** We used Leap Motion to recognize hand gestures. The sensor is located at the bottom of the frame to ensure that the capture of every gesture. Furthermore, two lines of a light-emitting diode (LED) strip are attached around the frame to provide feedback for the gestures. The form of Hand-in-O is frame-shaped to restrict the area of the gesture space. The rectangular frame is measured at a width of 650mm, a height of 300mm, and a thickness of 70mm, and this was appropriate for the gesture sensor's safe recognition range. For the finishing of the surface, matt light-gray colour spray was and sanded to diffuse the light of the LEDs. The front part was 5mm smaller than the back part, and they could be cascaded together.

**Software:** Gesture data detected by Leap Motion were calculated using Processing-3 and were used to control the LEDs in Arduino. When the user makes a specific gesture inside the frame, the data, such as the X/Y/Z value of the hands, roll/pitch/yaw, the existence of grab, and time are processed through Processing-3. In addition, using the JavaSound API, music control interactions in basic usability tests were implemented.

# 3 Exploratory study through Hand-in-O

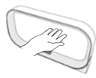
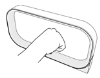
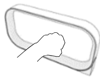
We conducted an exploratory study using our research prototype, Hand-in-O; first, a basic use experience test, and second, a design workshop. Our goal was to answer the following questions, (1) Does the frame-shaped gesture controller have accessibility in everyday life? (2) How could this device be used in the everyday home context? For this, we recruited twenty-one people in their 20s (13 females and 8 males) who are interested in home appliances. They participated as individuals and groups (eight individuals [P1 to P8], two two-person teams [P9 to P12], three three-person teams [P13 to P21]). The study was held in a home-style decorated lab (Figure 5) to provide participants with a more familiar environment.

*Figure 5. Exploratory study environment*

## 3.1 Interaction Techniques Used in the Study

For Hand-in-O's user study, a set of gestures and light feedbacks was needed. First, we set gestures to basic music controls to the right hand, such as play and stop, and to the left, volume and song conversion were set up as shown below (Table 1). In addition, for light feedback, the LED strips throughout the frame were mapped to the timeline of each music. All music has different colours, and as the music plays, the LEDs in that colour gradually turn on. When music is paused, the colours of the LEDs are blinking, and the brightness of the light is mapped with the volume (Figure 6). We used an additional speaker for emitting the music sound, which is synchronized with the Hand-in-O prototype.

*Table 1: Music control interactions based on hand gestures.*

| Hand | Play | Stop | Pause | Rewind | Forward |
|---|---|---|---|---|---|
| Right |  |  |  |  |  |
| **Hand** | **Volume Up** | **Volume Down** | **Mute** | **Previous Song** | **Next Song** |
| Left |  |  |  |  |  |

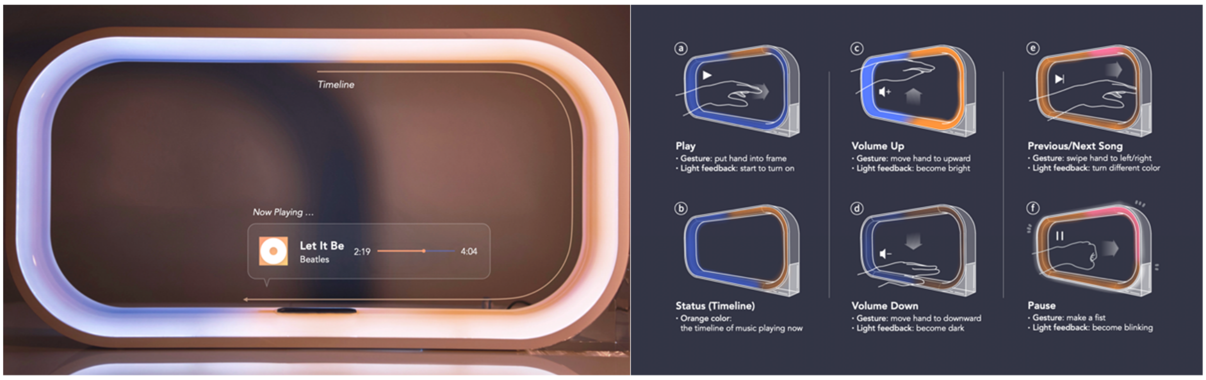



*Figure 6. LED light expressions of music controls according to hand gesture types.*

Gesture interactions were designed based on previous studies from SoundGrasp (Mitchell et al., 2011), Theremin (Glinsky, 2000), and FutureGrab (Han et al., 2012), as they mapped volume and pitch controls as the y-coordinate of the hand between the palm and the ground.

### 3.2 Basic Use Experiences of Hand-in-O

Using the above interaction techniques, we provided an instruction manual to the participants to learn how to operate Hand-in-O. We also let them have free time to explore the use of the prototype. Fourteen out of twenty-one participants remarked that Hand-in-O's frame-form allowed them to put a hand inside the frame. Most of them mentioned that it was like a home appliance at first glance—for example, a Dyson fan or training equipment. Nineteen participants could correctly guess all of the music control functions for each gesture. Regarding the results of performing gestures within Hand-in-O while having certain constraints, most of them answered that the difficulty level was reasonable; however, when they had to look at the Hand-in-O and switch hands, this made them feel uncomfortable. Hence, most of them desired to control the whole function by using only one hand. Also, performing gestures while holding a pen was not difficult because the gestures sensor recognized their hands well even when they were holding pens. Also, gestures from the centre of the frame were easily controlled without looking at the product. In addition, the most common issue was the participants' habit of clenching their fists while getting their hands out of the frame.

## 3.3 Design Workshop

### 3.3.1 Method

To explore the possibilities of adaptability of Hand-in-O in more detail, we conducted the design workshop right after the use experience exploration. In this workshop, we asked them to use gestural input, light feedback, and the frame's form in the design output for their brainstorming. They answered about their ideas, thoughts, and details about what function and context could be possible based on the experience of using this prototype. The workshop involved a brainstorming session through participant sketches and storytelling (Figure 7) to estimate how Hand-in-O can be applied to the home environment (in which context/ what form).

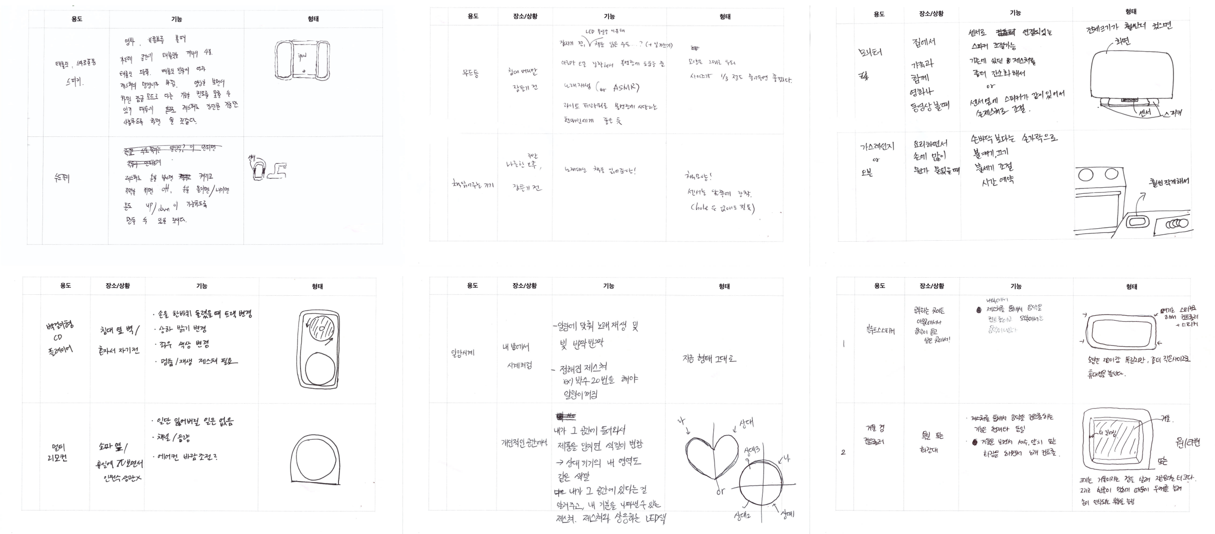
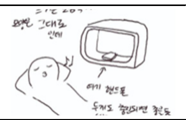
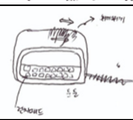


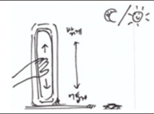
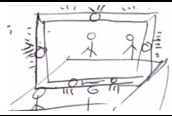
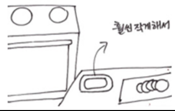
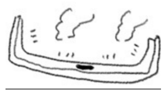
*Figure 7. Sketches and storytelling ideas: generated by participants during the design workshop.*

### 3.3.2 Results

In total, we could obtain 48 ideas through the design workshop. Those ideas were categorized as the purpose of the product. Before the design workshop, all the participants mentioned that the smooth finish and glossy interior would fit into home appliance products. Based on this, we could categorize 38 ideas of the workshop results as suggested usages of this product in household contexts (Table 2).

*Table 2: Categorization of workshop ideas based on the usage types.*

| Type | Usage | Example | Num |
|---|---|---|---|
| Multi-Controller | Home Appliance Control, Smart Device Control |  Smart TV controller | 11 |
| Music Player | Music Player with Additional Function |  Music player with wireless charger | 10 |
| Outdoor | Music Festival/Club/Party DJing |  MIDI controller | 10 |

| | | | |
|---|---|---|---|
| Light | Mood Light, Desk Lamp |  Mood light interface | 7 |
| Game | Game with Others |  Co-op game device | 3 |
| Kitchen | Oven Control, Refrigerator Door |  Gas range controller | 2 |
| Bathroom | Faucet Control, Mirror Light |  Faucet controller | 2 |
| Etc. | Communication Tool, Diffuser |  Diffuser controller | 3 |

### 3.3.3 Design Implications

Overall, through our effort to enhance our research prototype's quality, we could hear the participants' feelings regarding the prototype's finish and form have facilitated the use and brainstorming activities using the prototype and perceiving it as a technology probe. We could see that they tended to be more absorbed in their situations. Based on the participants' use experiences and design workshop, we could derive the following design implications.

***Limited space for gesture:*** Overall, we have found that Hand-in-O's frame shape positively affects usability. Although, gesture sensors, which are usually used in everyday life, are highly autonomous because space constraints are not visible. Participants from the user study commonly reported that the shape of the frame affected the hand's natural insertion. They also commented that they could use it more than other gesture interfaces, and the reason was the Hand-in-O's visual and physical gesture recognition range provision. In addition, the availability of interaction through both sides and the light feedback showed the applicability of this research prototype as a potential controller in various contexts at homes. Simultaneously, we found that if there were more variations in its form (e.g., size and width of the frames), it would lead to more implications during the user study. In sum, gestures could be applied in more diverse areas; by using the frame form's affordance, we could see its potentials that the interaction may attract users' curiosity about performing gesture interactions to control various types of media in homes. The tangible constraints, in which applying limitations through giving the gesture acting area may promote everyday gestural inputs. In other words, being too free for the gesture interaction would be difficult for using home electronic products, and guiding the gestures through the frame is one factor that complements this weakness.

***Double-sided co-interaction through the frame***: During the user study, more than half of the participants answered that the frame shape attracts users to put their hands in. During the workshop, they actively reached their hands and extended their arms into the device, mentioning a new experience. Interestingly, each team member was all friends; they sat opposite a friend or two and started to put their hands on the product (Figure 8) in a comfortable atmosphere. Three participants stated that they wished they could sit face-to-face and play games with friends and family. They pointed out that light feedback would follow a person who is using the device. When people use Hand-in-O and sit face-to-face, all sides of the lights would be turned on. Moreover, some participants implied that this manner of interaction using the product would be a new communication tool for family, friends, and lovers.

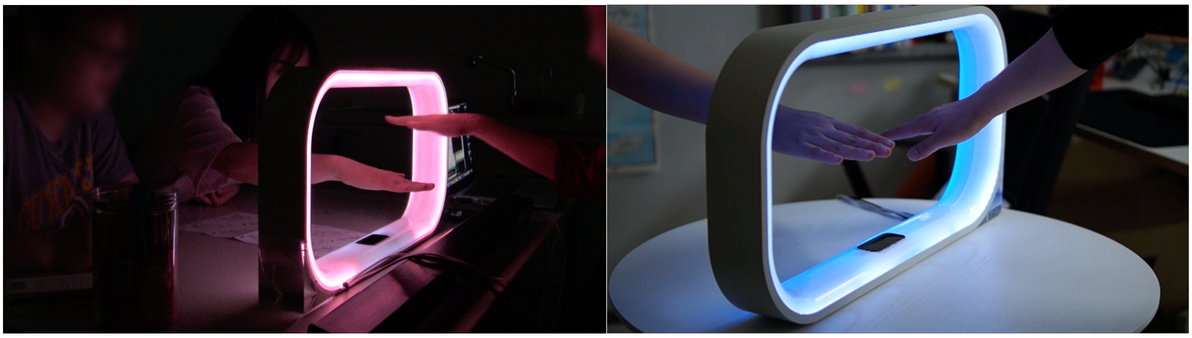


*Figure 8. The participants in the three-people group sat facing each other, using Hand-in-O in between them.*

## 4 Conclusion

We introduced the development and use of the frame-shaped gesture controller, Hand-in-O. As a technology probe, we used this artefact to explore the sensing and constraining gesture inputs' experiences, providing light feedback in the context of music control. Through an in-lab use experience test and a design workshop with twenty-one participants, we discovered that our approach provided a new gesture control experience for the participants due to the frame shape's effect and space constraints. We found the frame's shape successfully created a natural user interface by leading the user to use a hand for control purposes without instruction. Our study implies by applying proper physical constraints to the gestural area may promote filtering out unnecessary functions and focuses on the use of everyday gestural inputs in diverse ways.

**Acknowledgments.** This work was supported by NRF-2020R1F1A1054047 through the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT (MSIT).

## References

Aslan, I, Uhl, A, Meschtscherjakov, A & Tscheligi, M 2016, 'Design and exploration of mid-air authentication gestures', *ACM Transactions on Interactive Intelligent Systems*, vol. 6, no. 3, pp. 1-22.

Cabreira, T & Hwang, F 2016, 'How do novice older users evaluate and perform mid-air gesture interaction for the first time?', *Proceedings of the 9th Nordic Conference on Human-Computer Interaction*, pp. 1-6.

Chattopadhyay, D & Bolchini, D 2014, 'Touchless circular menus: toward an intuitive UI for touchless interactions with large displays', *Proceedings of 2014 International Working Conference on Advanced Visual Interfaces* pp. 33-40.

Chita, E, Sugiura, Y, Hashimoto, S, Kunze, K, Inami, M & Ogata, M 2015, 'Silhouette interactions: using the hand shadow as interaction modality', *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2015 ACM International Symposium on Wearable Computers*, pp. 69-72.

Glinsky, A 2000, *Theremin: ether music and espionage*, University of Illinois Press, Urbana and Chicago.

Gong, J, Xu, Z, Guo, Q, Seyed, T, Chen, A, Bi, X & Yang, XD 2018, 'WrisText: one-handed text entry on smartwatch using wrist gestures', *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, pp. 1-14.

Han, Y, Na, J, & Lee, K 2012, ‘FutureGrab: a wearable synthesizer using vowel formants’, *Proceedings of the 2012 International Conference on New Interfaces for Musical Expression*.

Intille, S 2002, ‘Designing a home of the future’, *IEEE Pervasive Computing*, vol. 1, no. 2, pp. 76-82.

Jones, E, Alexander, J, Andreou, A, Irani, P & Subramanian, S 2010, ‘GesText: accelerometer-based gestural text- entry systems’, *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pp. 2173-2182.

Jung, H & Stolterman, E 2012, ‘Digital form and materiality: propositions for a new approach to interaction design research’, *Proceedings of 7th Nordic Conference on Human-Computer Interaction: Making Sense Through Design* pp. 645-654.

Markussen, A, Jakobsen, MR & Hornbæk, K 2014, ‘Vulture: a mid-air word-gesture keyboard’, Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 1073-1082.

Matulic, F & Vogel, D 2018, ‘Multiray: multi-finger raycasting for large displays’, *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, pp. 1-13.

Mitchell, TJ 2011, ‘Soundgrasp: a gestural interface for the performance of live music’, *Proceedings of the 2011 International Conference on New Interfaces for Musical Expression*, pp. 465-468.

O'hara, K, Harper, R, Mentis, H, Sellen, A & Taylor, A 2013, ‘On the naturalness of touchless: putting the “interaction” back into NUI’, *ACM Transactions on Computer-Human Interaction*, vol. 20, no. 1, pp. 1-25.

Odom, W, Wakkary, R, Lim, YK, Desjardins, A, Hengeveld, B & Banks, R 2016, ‘From research prototype to research product’, *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, pp. 2549-2561.

Porcheron, M, Fischer, JE, Reeves, S & Sharples, S 2018, ‘Voice interfaces in everyday life’, *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, pp. 1-12.

Sørensen, T, Andersen, OD & Merritt, T 2015, ‘"Tangible Lights" in-air gestural control of home lighting’, *Proceedings of the 9th International Conference on Tangible, Embedded, and Embodied Interaction*, pp. 727-732.

Ujima, K, Kadomura, A & Siio, I 2014. ‘U-Remo: projection-assisted gesture control for home electronics’, *CHI'14 Extended Abstracts on Human Factors in Computing Systems*, pp. 1609-1614.

Walter, R, Bailly, G, & Müller, J 2013, ‘StrikeAPose: revealing mid-air gestures on public displays’, *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems,* pp. 841-850.

Wittorf, ML & Jakobsen, MR 2016, ‘Eliciting mid-air gestures for wall-display interaction’, *Proceedings of the 9th Nordic Conference on Human-Computer Interaction*, pp. 1-4.