Feedback of head gestures in audio-haptic remote communication

Huisman, Gijs; Lisini Baldi, Tommaso; D'Aurizio, Nicole; Prattichizzo, Domenico

DOI
10.1145/3460421.3478809

Publication date
2021

Document Version
Final published version

Published in
ISWC 2021 - Proceedings of the 2021 ACM International Symposium on Wearable Computers

Feedback of Head Gestures in Audio-haptic Remote Communication

Gijs Huisman
Delft University of Technology
Delft, the Netherlands
g.huisman@tudelft.nl

Tommaso Lisini Baldi
University of Siena
Siena, Italy
tommaso.lisini@unisi.it

Nicole D'Aurizio
University of Siena
Siena, Italy
ndaurizio@diism.unisi.it

Domenico Prattichizzo
University of Siena
Siena, Italy
dprattichizzo@unisi.it

ABSTRACT

In this brief, we present the preliminary design of a wearable system able to detect and haptically display head motions of conversation participants. The aim of the system is to allow for remote communication to not have to rely on visual social cues. To demonstrate the design principles of the system, we recorded data from a single participant during a remote walking conversation using Zoom.

CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**; **Interaction devices**; **Haptic devices**;

KEYWORDS

Haptics; Head Gestures; Nodding; Audio-Haptic Interaction; Remote Communication

ACM Reference Format:

Gijs Huisman, Tommaso Lisini Baldi, Nicole D'Aurizio, and Domenico Prattichizzo. 2021. Feedback of Head Gestures in Audio-haptic Remote Communication. In *2021 International Symposium on Wearable Computers (ISWC '21), September 21–26, 2021, Virtual, USA.* ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3460421.3478809

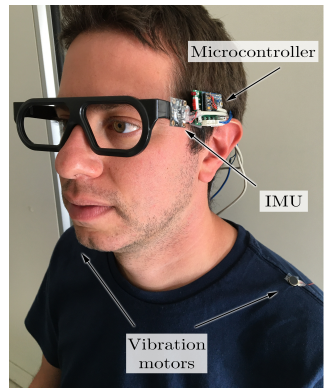


Figure 1: A user wearing the device.

1 INTRODUCTION

It has been said that sitting is 'the new smoking' [2], and, indeed, there is evidence for detrimental effects on health as a result of sitting for extended periods of time [31]. This is particularly worrying because in the European Union 39% of people who are employed carry out their work while seated [7]. Conversely, there is ample evidence that low-impact physical activity, such as walking, has positive effects on physical and mental well-being [10, 17, 21, 30]. Thus, supporting office workers to be more active could have benefits for their health and well-being.

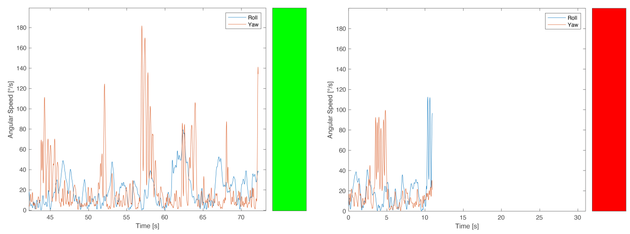
An important part of daily office work revolves around social communication with co-workers, either one-on-one or in larger meetings [18]. Technology offers the opportunity for remote meetings that afford audio-visual communication [11], but that do tie someone to their desk to use video call applications. Moreover, video call interactions can be especially exhausting, a phenomenon described as 'Zoom fatigue' [33], due to "excessive amounts of close-up eye gaze, cognitive load, increased self-evaluation from staring at video of oneself, and constraints on physical mobility" [3, p.1]. Solutions to Zoom fatigue necessitate reverting back to non-visual means of remote communication during which social cues, such as head gestures, are unavailable.

While some examples of remote meeting tools where participants can go outside to walk exist [1], these lack support for the communication of important social cues, such as facial expressions and head gestures (e.g., nodding and shaking the head), that are present in face-to-face communication. During typical social interactions, 65% of the information exchanged is nonverbal, and 72% of nonverbal communication is visual [16, 25]. Head nodding and shaking are particularly prevalent non-verbal cues in social interactions [4]. These head gestures do not only signal affirmation or disagreement (for a discussion of cultural variations see [15]), but also serve as an important bodily backchannel during conversation to provide feedback to a speaker [14, 28, 32]. This can be to signal that the speaker's turn is still in process, as well as can show affiliation with the speaker's stance by the listener [28]. Other research indicates that the amplitude of the head gesture also serves a communicative purpose. For example, head nods with high motion amplitude seem to indicate a prior utterance as news, while low motion amplitude nods merely indicate receipt of the prior utterance [32].

With the importance of head gestures in social interactions in mind, in order to create better remote communication tools that allow people to be active (e.g., by walking outside), new ways to communicate non-verbal cues, such as head gestures, need to be investigated. Here, we present the first design of a system that

ISWC '21, September 21–26, 2021, Virtual, USA

ACM ISBN 978-1-4503-8462-9/21/09.
https://doi.org/10.1145/3460421.3478809



Nodding identified. **Shaking identified.**

Figure 2: Recorded head gesture data. On the left side of each plot the angular velocity is reported, while on the right side the "yes"/"no" motion is identified with green/red color. The angular roll and yaw head velocities are reported in blue and red, respectively.

detects head motions of dyadic conversation participants and provides haptic feedback as a communicative social cue in a remote conversation.

2 RELATED WORK

There are several works that attempt to augment audio communication with haptic feedback through the integration of some form of tactile input (e.g., force-sensitive resistors) into mobile phones to produce vibrotactile output (or squeeze-type output [5]) during phone conversations [6, 12, 23]. Interactions with such systems show that participants use them to add emphasis to speech, use them as a signal in conversational turn-taking, engage in mimicry of haptic signals [6], as well as use these systems for persuasive, playful, and attention-getting interactions [23], not to mention the communication of affect and emotions [5, 29]. In the domain of augmentative and alternative communication devices [26] there have been several explorations of systems that use haptic feedback to provide blind, visually impaired [25], and people with deafblindness [22], with haptic feedback of social cues, including facial expressions [34], proxemics [19], eye contact [24], and head nodding [20, 25]. In the latter case, head nodding was either not automatically detected [25] or the haptic signal was binary [20].

3 SYSTEM OVERVIEW AND DEMONSTRATION

The system (see Figure 1) has three key characteristics: first, continuous measurement of head gestures. Second, discrimination between head nodding and shaking. Last, providing dynamic haptic feedback of head nodding and shaking. With dynamic haptic feedback we mean that the amplitude of the vibrations is directly related to the amplitude of the relevant head gesture. The system includes two vibration motors (Precision Microdrives Model No. 310-103) that can be placed bilaterally on the body (e.g., on the shoulders). Nodding activates both motors simultaneously in a rhythmic fashion, while shaking activates the motors in an alternating pattern. The haptic channel is particularly suitable to convey information in everyday environments where visual and auditory information might be disruptive, since the sense of touch is distributed, proximal, bidirectional, and private [13].

Head gestures are detected with an IMU (Inertial Measurement Unit (Invesense MPU6050) and a microcontroller (Teensy 3.2)) both of which are embedded in a pair of eyeglasses for easy wearability. An RN-42 Bluetooth antenna and a custom communication protocol allow the microcontroller to communicate wirelessly with a smartphone. The microcontroller collects the IMU data, handles data exchange with an application running on the smartphone, and controls activation of the motors. To enable remote communication of head gestures in dyadic conversation, the detected motions are transmitted through a dedicated server via the Internet. This way, head gestures of one person can be felt as haptic feedback by a remotely located second person.

To demonstrate the functioning of the system, we recorded data from a single participant during a remote walking conversation using Zoom. The person wearing the system walked outside and was interviewed for approximately five minutes by an interviewer. The interview consisted of three parts: introduction and small talk, instructions (i.e., a recipe), and discussion (i.e., a survival scenario). Audio and video recordings of the conversation, as well as the recorded head gesture data, are available as supplementary materials. Figure 2 visualizes the recorded head gesture data. It can be observed how the system can distinguish between nodding and shaking of the head at different amplitudes during a conversation.

4 DISCUSSION AND CONCLUSIONS

We presented the first design of a wearable system that enables the communication of head gestures through dynamic haptic feedback during a remote dyadic walking conversation.

A demonstration of the system's capabilities to detect head gestures illustrated how the device can distinguish between head nodding and shaking (though some noise of general head motions is still present), can provide detailed information about gesture amplitudes (see [32] for the importance of head gesture amplitude), and can provide insights into the timing of head gestures during conversations [9, 28, 32].

Planned future work involves making improvements to the physical form and hardware of the system. We are currently considering different wearable form factors aside from eyeglasses, such as wireless earphones. We are also investigating different actuator types, such as voice coils, for more refined haptic feedback and are experimenting with the placement of the actuators on the user's body. Finally, we are exploring ways in which the system could be used by more than two users through haptic frequency modulation and the placement of multiple actuators to represent multiple conversation partners.

In addition to improvements to the system, we have planned several studies to investigate the use and impact of the system during remote conversations. First, we aim to investigate how feeling dynamic haptic feedback from a conversation partner's head gestures influences conversation dynamics [28, 32] and interpersonal synchrony [8, 9]. Second, we are interested in whether haptic head gestures in non-visual remote communication can contribute to consensus building during discussions. To this end, we plan to conduct studies where participants both wear the system and engage in a discussion to see whether the addition of haptic head gesture feedback improves consensus building, for example, through improved conversation dynamics (e.g., being able to build on each other's social cues). Finally, we aim to explore how being physically active during remote audio-haptic communication, can impact creativity (see [27]). We will explore how haptic head gestures can contribute to enhancing creativity by allowing for the communication of non-verbal cues in audio-haptic remote communication settings.

REFERENCES

[1] Aino Ahtinen, Eeva Andrejeff, Maiju Vuolle, and Kaisa Väänänen. 2016. Walk as you work: user study and design implications for mobile walking meetings. In *Proceedings of the 9th Nordic Conference on Human-Computer Interaction*. 1–10.

[2] Benjamin Baddeley, Sangeetha Sornalingam, and Max Cooper. 2016. Sitting is the new smoking: where do we stand? *British Journal of General Practice* 66, 646 (2016), 258–258.

[3] Jeremy N Bailenson. 2021. Nonverbal overload: A theoretical argument for the causes of Zoom fatigue. *Technology, Mind, and Behavior* 2, 1 (2021).

[4] Konstantinos Bousmalis, Marc Mehu, and Maja Pantic. 2009. Spotting agreement and disagreement: A survey of nonverbal audiovisual cues and tools. In *2009 3rd international conference on affective computing and intelligent interaction and workshops*. IEEE, 1–9.

[5] Angela Chan, Francis Quek, Haard Panchal, Joshua Howell, Takashi Yamauchi, and Jinsil Hwaryoung Seo. 2021. The Effect of Co-Verbal Remote Touch on Electrodermal Activity and Emotional Response in Dyadic Discourse. *Sensors* 21, 1 (2021), 168.

[6] Angela Chang, Sile O'Modhrain, Rob Jacob, Eric Gunther, and Hiroshi Ishii. 2002. ComTouch: design of a vibrotactile communication device. In *Proceedings of the 4th conference on Designing interactive systems: processes, practices, methods, and techniques*. 312–320.

[7] Eurostat. 2019. *Sit at work? You are one of 39%.* https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20190305-1

[8] Satinder P Gill. 2012. Rhythmic synchrony and mediated interaction: towards a framework of rhythm in embodied interaction. *AI & society* 27, 1 (2012), 111–127.

[9] Aman Gupta, Finn L Strivens, Benjamin Tag, Kai Kunze, and Jamie A Ward. 2019. Blink as you sync: Uncovering eye and nod synchrony in conversation using wearable sensing. In *Proceedings of the 23rd International Symposium on Wearable Computers*. 66–71.

[10] Sarah Hanson and Andy Jones. 2015. Is there evidence that walking groups have health benefits? A systematic review and meta-analysis. *British journal of sports medicine* 49, 11 (2015), 710–715.

[11] E Jeffrey Hill, Maria Ferris, and Vjollca Märtinson. 2003. Does it matter where you work? A comparison of how three work venues (traditional office, virtual office, and home office) influence aspects of work and personal/family life. *Journal of Vocational Behavior* 63, 2 (2003), 220–241.

[12] Eve Hoggan, Craig Stewart, Laura Haverinen, Giulio Jacucci, and Vuokko Lantz. 2012. Pressages: augmenting phone calls with non-verbal messages. In *Proceedings of the 25th annual ACM symposium on User interface software and technology*. 555–562.

[13] Lynette A Jones and Nadine B Sarter. 2008. Tactile displays: Guidance for their design and application. *Human factors* 50, 1 (2008), 90–111.

[14] Viktoria A Kettner and Jeremy IM Carpendale. 2013. Developing gestures for no and yes: Head shaking and nodding in infancy. *Gesture* 13, 2 (2013), 193–209.

[15] Sotaro Kita. 2009. Cross-cultural variation of speech-accompanying gesture: A review. *Language and cognitive processes* 24, 2 (2009), 145–167.

[16] Mark L Knapp, Judith A Hall, and Terrence G Horgan. 2013. *Nonverbal communication in human interaction.* Cengage Learning.

[17] I-Min Lee and David M Buchner. 2008. The importance of walking to public health. *Medicine & Science in Sports & Exercise* 40, 7 (2008), S512–S518.

[18] Alexandra Luong and Steven G Rogelberg. 2005. Meetings and more meetings: The relationship between meeting load and the daily well-being of employees. *Group Dynamics: Theory, Research, and Practice* 9, 1 (2005), 58.

[19] Troy McDaniel, Sreekar Krishna, Vineeth Balasubramanian, Dirk Colbry, and Sethuraman Panchanathan. 2008. Using a haptic belt to convey non-verbal communication cues during social interactions to individuals who are blind. In *2008 IEEE International Workshop on Haptic Audio visual Environments and Games*. IEEE, 13–18.

[20] María Elena Meza-de Luna, Juan R Terven, Bogdan Raducanu, and Joaquín Salas. 2019. A Social-Aware Assistant to support individuals with visual impairments during social interaction: A systematic requirements analysis. *International Journal of Human-Computer Studies* 122 (2019), 50–60.

[21] Jeremy N Morris and Adrianne E Hardman. 1997. Walking to health. *Sports medicine* 23, 5 (1997), 306–332.

[22] Misako Nambu, Akira Okamoto, Shigeki Miyoshi, and Masatsugu Sakajiri. 2008. Dialog support for deafblind persons by conveying backchannels through vibration. In *International Conference on Computers for Handicapped Persons*. Springer, 686–689.

[23] Young-Woo Park, Seok-Hyung Bae, and Tek-Jin Nam. 2012. How do couples use cheektouch over phone calls?. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 763–766.

[24] Shi Qiu, Jun Hu, Ting Han, Hirotaka Osawa, and Matthias Rauterberg. 2020. An Evaluation of a Wearable Assistive Device for Augmenting Social Interactions. *IEEE Access* 8 (2020), 164661–164677.

[25] Joshua Rader, Troy McDaniel, Artemio Ramirez, Shantanu Bala, and Sethuraman Panchanathan. 2014. A Wizard of Oz Study Exploring How Agreement/Disagreement Nonverbal Cues Enhance Social Interactions for Individuals Who Are Blind. In *International Conference on Human-Computer Interaction*. Springer, 243–248.

[26] Kiley Sobel, Alexander Fiannaca, Jon Campbell, Harish Kulkarni, Ann Paradiso, Ed Cutrell, and Meredith Ringel Morris. 2017. Exploring the Design Space of AAC Awareness Displays. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. 2890–2903.

[27] Hannah Steinberg, Elizabeth A Sykes, Tim Moss, Susan Lowery, Nick LeBoutillier, and Alison Dewey. 1997. Exercise enhances creativity independently of mood. *British Journal of Sports Medicine* 31, 3 (1997), 240–245.

[28] Tanya Stivers. 2008. Stance, alignment, and affiliation during storytelling: When nodding is a token of affiliation. *Research on language and social interaction* 41, 1 (2008), 31–57.

[29] Katja Suhonen, Sebastian Müller, Jussi Rantala, Kaisa Väänänen-Vainio-Mattila, Roope Raisamo, and Vuokko Lantz. 2012. Haptically augmented remote speech communication: a study of user practices and experiences. In *Proceedings of the 7th Nordic conference on human-computer interaction: making sense through design*. 361–369.

[30] Marcus Tschentscher, David Niederseer, and Josef Niebauer. 2013. Health benefits of Nordic walking: a systematic review. *American journal of preventive medicine* 44, 1 (2013), 76–84.

[31] Jannique GZ Van Uffelen, Jason Wong, Josephine Y Chau, Hidde P Van Der Ploeg, Ingrid Riphagen, Nicholas D Gilson, Nicola W Burton, Genevieve N Healy, Alicia A Thorp, Bronwyn K Clark, et al. 2010. Occupational sitting and health risks: a systematic review. *American journal of preventive medicine* 39, 4 (2010), 379–388.

[32] Kevin A Whitehead. 2011. Some uses of head nods in "third position" in talk-in-interaction. *Gesture* 11, 2 (2011), 103–122.

[33] Brenda K Wiederhold. 2020. Connecting through technology during the coronavirus disease 2019 pandemic: Avoiding "Zoom Fatigue".

[34] Shamima Yasmin and Sethuraman Panchanathan. 2016. Haptic mirror: A platform for active exploration of facial expressions and social interaction by individuals who are blind. In *Proceedings of the 15th ACM SIGGRAPH Conference on Virtual-Reality Continuum and Its Applications in Industry-Volume 1*. 319–329.