ChairMX: On-Chair Input for Interactive Media Consumption Experiences for Everyone, Everywhere

Radu-Daniel Vatavu
MintViz Lab, MANSiD Center, Ştefan cel Mare University of Suceava
Suceava, Romania
radu.vatavu@usm.ro

Laura-Bianca Bilius
MintViz Lab, MANSiD Center, Ştefan cel Mare University of Suceava
Suceava, Romania
laura.bilius@usm.ro

Alexandru-Tudor Andrei
MintViz Lab, MANSiD Center, Ştefan cel Mare University of Suceava
Suceava, Romania
tudor.andrei@usm.ro

Mihail Terenti
MintViz Lab, MANSiD Center, Ştefan cel Mare University of Suceava
Suceava, Romania
mihail.terenti@usm.ro

Adrian-Vasile Catană
MintViz Lab, MANSiD Center, Ştefan cel Mare University of Suceava
Suceava, Romania
adrian.catana@usm.ro

Alexandru-Ionuţ Şiean
MintViz Lab, MANSiD Center, Ştefan cel Mare University of Suceava
Suceava, Romania
alexandru.siean@usm.ro

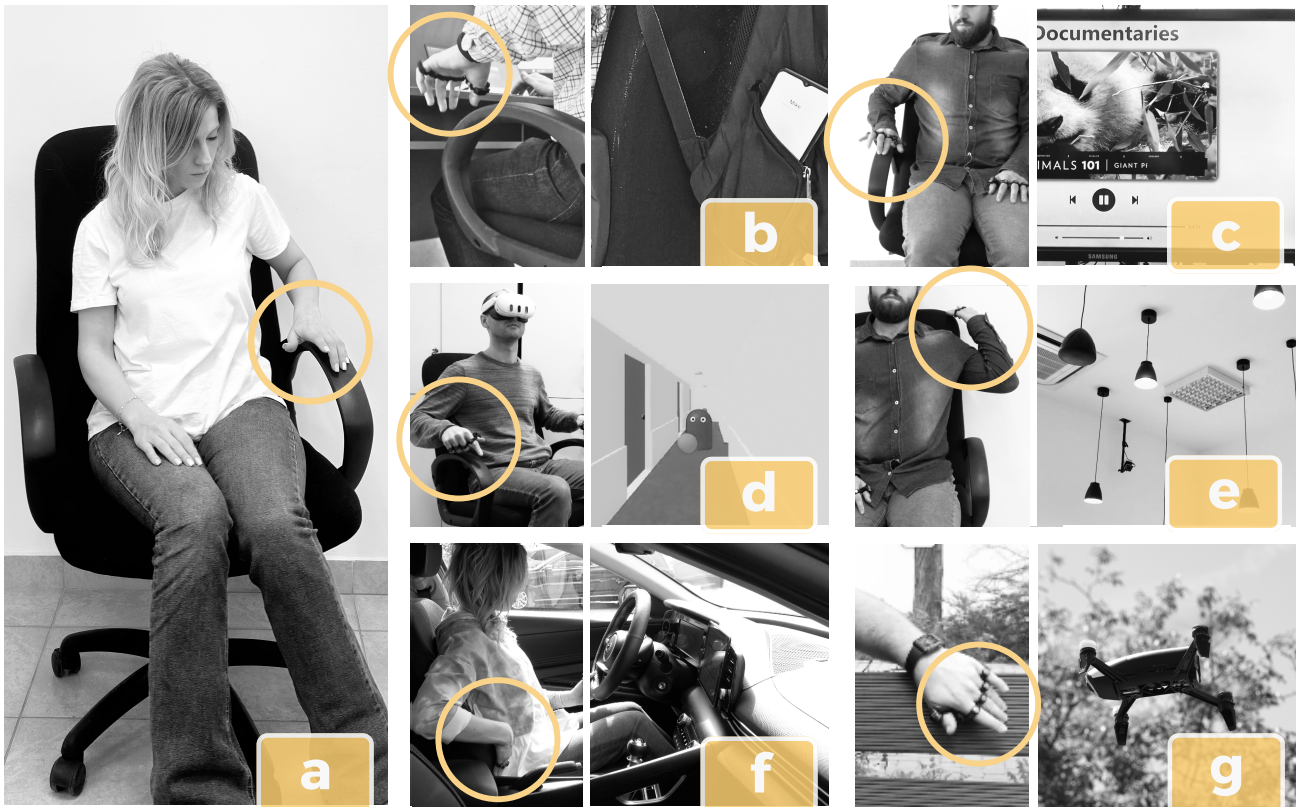

Figure 1: ChairMX is our on-chair gesture input technology for interactive media consumption experiences where chairs are leveraged as input devices, e.g., a tap on the armrest (a) effects a command on a connected device or enables access to digital media on a remote display. We demonstrate applications of ChairMX from smartphone shortcuts (b) to television control (c), interactions in virtual environments (d), control of smart home devices (e), in-vehicle interactions (f), and drone control (g). Due to our system design approach involving a wearable device for the hand, ChairMX is readily deployable to all chairs.

IMX '24, June 12–14, 2024, Stockholm, Sweden

ACM ISBN 979-8-4007-0503-8/24/06
https://doi.org/10.1145/3639701.3661090

ABSTRACT

We introduce ChairMX, on-chair input technology for novel interactive media consumption experiences through the chair. ChairMX is the end result of an elaborate four-stage research and development process involving a systematic literature review of the extent in which chairs have been used in interactive systems, involvement of potential end users to elicit their preferences for on-chair input, engineering on-chair gesture input recognition technology with wearables, and exploration of application opportunities. By leveraging a ring-like form factor wearable, ChairMX is a readily deployable technology, working for uninstrumented chairs everywhere and enabling a variety of use case scenarios involving interactive media consumption, from the living room to public environments.

CCS CONCEPTS

• **Human-centered computing** → **Gestural input**; **Empirical studies in HCI**; **User studies**.

KEYWORDS

Gesture input, chairs, on-chair interactions, touch input, interactive media experiences

ACM Reference Format:

Radu-Daniel Vatavu, Laura-Bianca Bilius, Alexandru-Tudor Andrei, Mihail Terenti, Adrian-Vasile Catană, and Alexandru-Ionuţ Şiean. 2024. ChairMX: On-Chair Input for Interactive Media Consumption Experiences for Everyone, Everywhere. In *ACM International Conference on Interactive Media Experiences (IMX '24), June 12–14, 2024, Stockholm, Sweden.* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3639701.3661090

1 INTRODUCTION

Chairs are ubiquitous, facilitating work, travel, and leisure activities. People spend a significant amount of their time sitting with estimates showing a daily average of 7 to 8 hours [26,31], of which at least two are spent watching television and videos. In fact, the most prevalent forms of digital entertainment—cinema, theater halls, living room entertainment—involve sitting, while mobile media consumption frequently involves sitting, e.g., while commuting [5,30].

Since chairs accompany media consumption in diverse contexts of use, from the comfort of one's home to outside-the-home settings, we propose integrating them into the media consumption experience as input devices. Specifically, the chair's surface can provide a wide, versatile input space for interacting with media content [1], e.g., from a simple tap on the armrest or seat to expressive multitouch, stroke-gesture, and grasp-based input involving various parts of the chair; see Figure 1a. In this paper, we present our process of making on-chair gesture input practical, leading to the ChairMX (on-Chair input for Media eXperiences) technology, for which we provide several demonstrations spanning smart homes, VR, mobile devices, drones, and vehicles; see Figures 1b to 1g.

2 CHAIRMX SCIENCE AND TECHNOLOGY

ChairMX is the end result of an elaborate four-stage research approach, illustrated in Figure 2, as follows.

Stage #1. Understanding the extent of chairs being used for interactive computer systems. The results of a systematic literature review involving 903 references from the ACM Digital Library and IEEE Xplore databases, which we conducted on the topic of chair-based interaction and interfaces [1], revealed that chairs have been targeted only sporadically in the Human-Computer Interaction community. When employed, chairs were used for interactions involving body posture adjustments, such as tilting and rotating [12,17,22], whereas prevalent input modalities, such as touch, have been less examined [7,24]. More details are available in [1]. These findings led to Stage 2, presented next, where we examined the design space of gesture input on the chair's surface.

Stage #2. Involvement of potential end users and collecting user preferences for on-chair input. This stage involved understanding users' preferences for on-chair input, including aspects of comfort and suitability of on-chair interactions. Our findings, from a sample of 54 participants [1] that proposed a total of 1,620 gestures, revealed a preference for unimanual input implemented with touch (e.g., a two-finger tap on the armrest to cancel an alarm), stroke gestures (e.g., drawing letter "M" for access to messages), and hand poses (e.g., placing the palm on the seat to access contacts), including bimanual gestures (e.g., touching the seat with both hands to turn the TV on/off). We also found that on-chair gestures were generally perceived as ease to use, recall, and socially acceptable to be performed in public; see Andrei *et al.* [1] for details.

Stage #3. Engineering on-chair input technology. To streamline the integration of everyday chairs into media consumption experiences for a wide range of applications, contexts of use, and user categories, we adopted three design requirements:

- DR_1: *Simple, fast, and familiar input.* To implement this requirement, we adopted touch input in the form of taps on various chair parts, e.g., the armrest, backrest, or seat. Touch input is mainstream on mobile devices and, consequently, familiar to users. At the same time, it is simple and fast, but also enables a myriad variations in terms of location, finger, and tap behavior, e.g., a three-finger double tap.
- DR_2: *No chair left out.* To make ChairMX widely available, we adopted a design approach where the chairs are not instrumented, while on-chair input is detected through a wearable. Our demonstrations use Tap Strap 2,[1] a ring-like [28] device featuring a 3-axis accelerometer per finger, built-in tap input detection, and a low weight of 200g only; see Figures 1b-1g. Tap Strap 2 connects through Bluetooth 4.0 to our smartphone application implementing ChairMX. Tap locations are recognized using the built-in accelerometers that provide the 3D orientation of the hand using a technique similar to [21].
- DR_3: *High accessibility.* Whereas DR_2 targets ChairMX availability everywhere, DR_3 is about the accessibility of ChairMX interactions for everyone. Although not specifically addressed in the demonstrations in Section 3, our studies involving wheelchair users [3,4] revealed than on-wheelchair input on the armrests, readily implementable through a chairable [8], are highly rated for remote control tasks.

Stage #4. Applications of ChairMX for interactive media consumption. At this stage, we explored application opportunities of ChairMX for uninstrumented chairs in various indoor and outdoor settings; see Figure 1 for examples and Section 3 for details.

[1] https://www.tapwithus.com/product/tap-strap-2

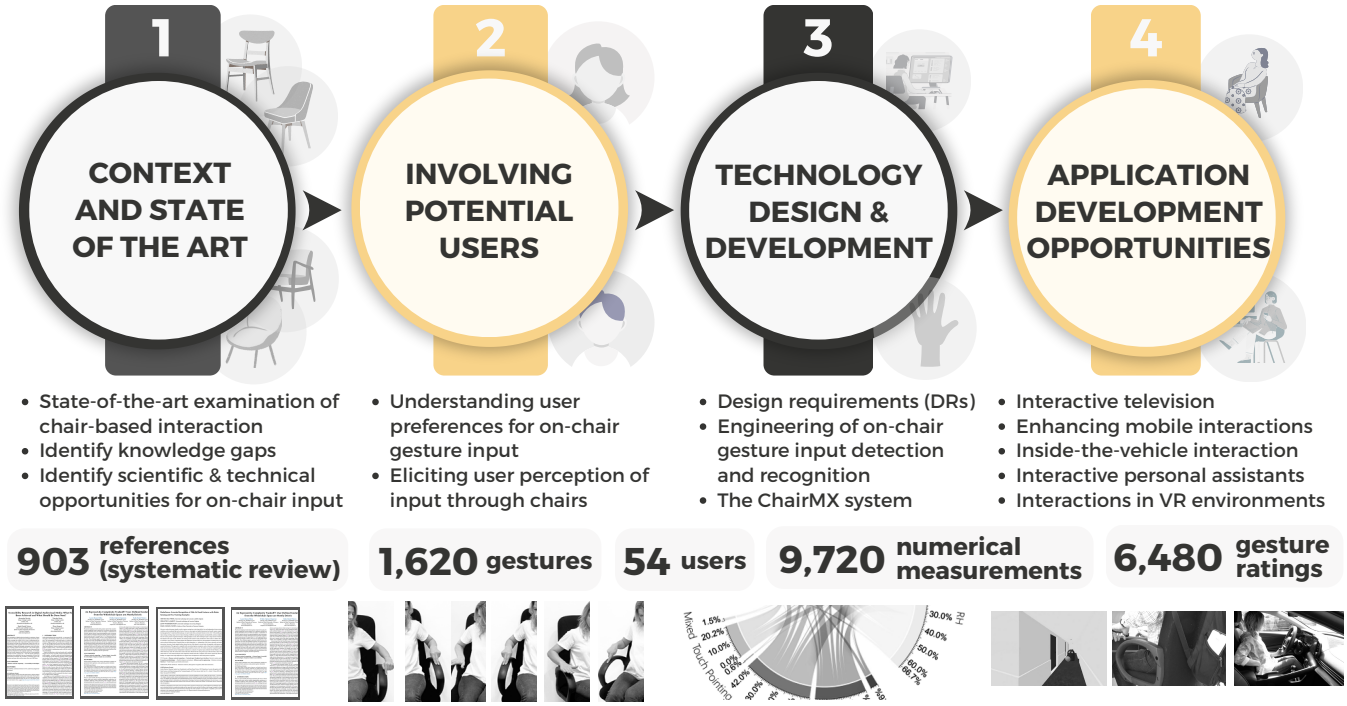

Figure 2: The four-stage research approach and involved effort leading to the ChairMX technology and applications.

3 APPLICATIONS OF CHAIRMX

Due to the ubiquity of chairs and our specific design approach of not instrumenting the chairs themselves, ChairMX supports a wide range of chairs featuring various structural parts (e.g., seat, backrest, armrest), applications (e.g., media access or remote control), contexts of use (e.g., smart homes, VR, etc.), and private and public environments for novel media consumption experiences. In the following, we present a selected set of demonstrations, informed by our literature reviews [1,5,10,28], user studies [1,6,14,25], and previous systems involving gesture input technology [2,29,32] in the application areas for which we pioneer ChairMX; see https://youtu.be/l-U_4Od7BhI for a video summary.

- *Smartphone shortcuts.* Mobile interactions are mainstream, but the smartphone may not always be easily reachable (e.g., when inside a pocket or bag), its use not always socially acceptable (e.g., during a meeting), or the user may be momentarily not available (e.g., when engaged in an attention demanding task) [13,23]. To enable smartphone shortcuts while the user is sitting, without actually reaching for the smartphone itself, we implemented ChairMX through taps on the armrest; see Figure 1b. In this application, when the user is busy or not available and the phone is ringing, a simple armrest tap rejects or silences the incoming call.
- *Television control.* Television watching is a mainstream form of home entertainment. In line with previous research on gesture input for television [27,32], we implemented ChairMX with two tap input variations (single and two-finger taps) on the armrest and seat for channel navigation and movie genre selection; see Figure 1c. In this context, the chair becomes a readily available remote control, complementing other innovative TV interaction styles involving furniture [29] and everyday objects within the living room [9,19].
- *Interactions in virtual environments.* Current gesture-based interaction techniques for VR environments involve controllers, gloves, or free-hand input with various advantages for users [16]. In this space, ChairMX provides a complementary interaction style when sitting in a chair. We implemented three on-chair gestures: index-finger taps on the left and right armrests for left/right navigation in the virtual environment, and a tap performed on the right side of the seat to start/stop movement, respectively; see Figure 1d. In this specific application, the chair's surface conveniently provides passive haptic feedback, known to be helpful to users for confirming interactions within virtual environments [25].
- *Control of smart home devices.* More and more devices and home appliances feature Internet connectivity and IoT compatibility, among which the possibility of controlling them remotely, including through personalized commands [9,20]. We leveraged a few locations on the seat and backrest for specifying four color and intensity moods of Philips Hue smart lights using simple taps, e.g., a tap on the backrest left side changes the room mood to bluish; see Figure 1e.
- *Inside-the-vehicle interactions.* Modern vehicles feature smart connectivity and interactivity, including support for interactive media consumption inside the vehicle—see Bilius and Vatavu [5] for a review—with current gesture-based techniques involving on-wheel, touchscreen, and mid-air input [6,11,15]. To demonstrate ChairMX in this environment,

we used taps performed in two locations, easily accessible on the left and right of the driver's seat, for previous and next navigation commands in a music player app; see Figure 1f.
- *Interactions with drones.* As another example of outdoor deployment of ChairMX, we implemented a drone control application, where a tap performed on a park bench controls drone take-off and landing; see Figure 1g. This application falls into recent developments in human-drone interaction [18] by providing a complementary interaction technique for drones, not requiring a controller or a hand-held device.

All of these demonstrative applications were implemented using one or two-finger taps performed at various locations on the chairs' surface, such as the armrest, seat, and backrest, respectively. These gestures are fast, can be robustly detected, and are familiar to users due to the mainstream interaction paradigm involving touch and multitouch input on mobile devices. Future developments may consider other gesture types, such as stroke gestures [1], representing letters, numbers, and other symbols drawn on the chair's surface. At the conference, several demonstrations of ChairMX will be available to the attendees, including smartphone shortcuts, media control on a remote display, interaction with smart lights, and navigating in a virtual environment using an everyday, uninstrumented chair.

4 CONCLUSION

We presented on-chair gesture input for interactive media experiences where the chair surface acts as the input device. ChairMX is a readily deployable technology, available for uninstrumented chairs everywhere, and enabling a variety of use case scenarios and application opportunities towards novel interactive media consumption experiences from the living room to public environments.

ACKNOWLEDGMENTS

This work was conducted within the Machine Intelligence and Information Visualization Research Laboratory of the Ştefan cel Mare University of Suceava. This work is also supported by the NetZeRoCities Competence Center, funded by European Union - NextGenerationEU and Romanian Government, under the National Recovery and Resilience Plan for Romania, contract no. 760007/30.12.2022 with the Romanian Ministry of Research, Innovation and Digitalization through the specific research projects P3, Smart and sustainable buildings and P4, Smart mobility and infrastructure.

REFERENCES

[1] Alexandru-Tudor Andrei, Laura-Bianca Bilius, and Radu-Daniel Vatavu. 2024. Take a Seat, Make a Gesture: Charting User Preferences for On-Chair and From-Chair Gesture Input. In *Proceedings of the CHI Conference on Human Factors in Computing Systems (CHI '24)*. ACM, New York, NY, USA, 17 pages. https://doi.org/10.1145/3613904.3642028

[2] Alexandru-Tudor Andrei, Alexandru-Ionut Şiean, and Radu-Daniel Vatavu. 2022. Tap4Light: Smart Lighting Interactions by Tapping with a Five-Finger Augmentation Device. In *Proceedings of the 13th Augmented Human International Conference (AH '22)*. ACM, New York, NY, USA, Article 4, 2 pages. https://doi.org/10.1145/3532525.3532535

[3] Laura-Bianca Bilius, Ovidiu-Ciprian Ungurean, and Radu-Daniel Vatavu. 2023. An Expressivity-Complexity Tradeoff?: User-Defined Gestures from the Wheelchair Space Are Mostly Deictic. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems (CHI EA '23)*. ACM, New York, NY, USA, Article 35, 8 pages. https://doi.org/10.1145/3544549.3585695

[4] Laura-Bianca Bilius, Ovidiu-Ciprian Ungurean, and Radu-Daniel Vatavu. 2023. Understanding Wheelchair Users' Preferences for On-Body, In-Air, and On-Wheelchair Gestures. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23)*. ACM, New York, NY, USA, Article 78, 16 pages. https://doi.org/10.1145/3544548.3580929

[5] Laura-Bianca Bilius and Radu-Daniel Vatavu. 2020. A Synopsis of Input Modalities for In-Vehicle Infotainment and Consumption of Interactive Media. In *Proceedings of the 2020 ACM International Conference on Interactive Media Experiences (IMX '20)*. ACM, New York, NY, USA, 195–199. https://doi.org/10.1145/3391614.3399400

[6] Laura-Bianca Bilius and Radu-Daniel Vatavu. 2021. A Multistudy Investigation of Drivers and Passengers' Gesture and Voice Input Preferences for In-Vehicle Interactions. *Journal of Intelligent Transportation Systems* 25, 2 (2021), 197–220. https://doi.org/10.1080/15472450.2020.1846127

[7] Philipp Brauner, Julia van Heek, Martina Ziefle, Nur Al-huda Hamdan, and Jan Borchers. 2017. Interactive FUrniTURE: Evaluation of Smart Interactive Textile Interfaces for Home Environments. In *Proceedings of the 2017 ACM International Conference on Interactive Surfaces and Spaces (ISS '17)*. ACM, New York, NY, USA, 151–160. https://doi.org/10.1145/3132272.3134128

[8] Patrick Carrington, Amy Hurst, and Shaun K. Kane. 2014. The Gest-Rest: A Pressure-Sensitive Chairable Input Pad for Power Wheelchair Armrests. In *Proceedings of the 16th International ACM SIGACCESS Conference on Computers & Accessibility (ASSETS '14)*. ACM, New York, NY, USA, 201–208. https://doi.org/10.1145/2661334.2661374

[9] Alexandru-Ionut Şiean, Cristian Pamparau, Arthur Sluÿters, Radu-Daniel Vatavu, and Jean Vanderdonckt. 2023. Flexible Gesture Input with Radars: Systematic Literature Review and Taxonomy of Radar Sensing Integration in Ambient Intelligence Environments. *Journal of Ambient Intelligence and Humanized Computing* 14 (2023), 7967–7981. https://doi.org/10.1007/s12652-023-04606-9

[10] Alexandru-Ionut Şiean, Radu-Daniel Vatavu, and Jean Vanderdonckt. 2021. Taking That Perfect Aerial Photo: A Synopsis of Interactions for Drone-based Aerial Photography and Video. In *Proceedings of the 2021 ACM International Conference on Interactive Media Experiences (IMX '21)*. ACM, New York, NY, USA, 275–279. https://doi.org/10.1145/3452918.3465484

[11] Tanja Döring, Dagmar Kern, Paul Marshall, Max Pfeiffer, Johannes Schöning, Volker Gruhn, and Albrecht Schmidt. 2011. Gestural interaction on the steering wheel: reducing the visual demand. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11)*. ACM, New York, NY, USA, 483–492. https://doi.org/10.1145/1978942.1979010

[12] Alex Endert, Patrick Fiaux, Haeyong Chung, Michael Stewart, Christopher Andrews, and Chris North. 2011. ChairMouse: Leveraging Natural Chair Rotation for Cursor Navigation on Large, High-Resolution Displays. In *CHI '11 Extended Abstracts on Human Factors in Computing Systems (CHI EA '11)*. ACM, New York, NY, USA, 571–580. https://doi.org/10.1145/1979742.1979628

[13] Anja Exler, Marcel Braith, Andrea Schankin, and Michael Beigl. 2016. Preliminary investigations about interruptibility of smartphone users at specific place types. In *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct (UbiComp '16)*. ACM, New York, NY, USA, 1590–1595. https://doi.org/10.1145/2968219.2968554

[14] Bogdan-Florin Gheran, Jean Vanderdonckt, and Radu-Daniel Vatavu. 2018. Gestures for Smart Rings: Empirical Results, Insights, and Design Implications. In *Proceedings of the Designing Interactive Systems Conference (DIS '18)*. ACM, New York, NY, USA, 623–635. https://doi.org/10.1145/3196709.3196741

[15] Bogdan-Florin Gheran and Radu-Daniel Vatavu. 2020. From Controls on the Steering Wheel to Controls on the Finger: Using Smart Rings for In-Vehicle Interactions. In *Companion Publication of the 2020 ACM Designing Interactive Systems Conference (DIS' 20 Companion)*. ACM, New York, NY, USA, 299–304. https://doi.org/10.1145/3393914.3395851

[16] Nour Halabi, Evan Jones, and Pejman Mirza-Babaei. 2023. Unleashing Immersive Experiences: The Power of Gesture-Based VR Interaction. *Interactions* 30, 6 (nov 2023), 52–55. https://doi.org/10.1145/3626247

[17] Abraham M. Hashemian, Ashu Adhikari, Ernst Kruijff, Markus von der Heyde, and Bernhard E. Riecke. 2023. Leaning-Based Interfaces Improve Ground-Based VR Locomotion in Reach-the-Target, Follow-the-Path, and Racing Tasks. *IEEE Transactions on Visualization and Computer Graphics* 29, 3 (2023), 1748–1768. https://doi.org/10.1109/TVCG.2021.3131422

[18] Viviane Herdel, Lee J. Yamin, and Jessica R. Cauchard. 2022. Above and Beyond: A Scoping Review of Domains and Applications for Human-Drone Interaction. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems (CHI '22)*. ACM, New York, NY, USA, Article 463, 22 pages. https://doi.org/10.1145/3491102.3501881

[19] Yoshinori Kawasaki, Takeo Igarashi, Takashi Ajioka, and Ikuji Honda. 2005. Vision-based Gestural Interaction Using Plush Toys. In *UIST '05 Adjunct Proceedings*. ACM, USA, 2 pages. https://uist.acm.org/archive/adjunct/2005/pdf/demos/d2-kawasaki.pdf

[20] Yihua Lou, Wenjun Wu, Radu-Daniel Vatavu, and Wei-Tek Tsai. 2017. Personalized Gesture Interactions for Cyber-Physical Smart-Home Environments. *Science China Information Sciences* 60, 7 (2017), 072104:1–15. https://doi.org/10.1007/s11432-015-1014-7

[21] Irina Popovici, Radu-Daniel Vatavu, and Wenjun Wu. 2019. TV Channels in Your Pocket! Linking Smart Pockets to Smart TVs. In *Proceedings of the 2019 ACM*

International Conference on Interactive Experiences for TV and Online Video (TVX '19). ACM, New York, NY, USA, 193–198. https://doi.org/10.1145/3317697.3325119

[22] Kathrin Probst, David Lindlbauer, Michael Haller, Bernhard Schwartz, and Andreas Schrempf. 2014. A Chair as Ubiquitous Input Device: Exploring Semaphoric Chair Gestures for Focused and Peripheral Interaction. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*. ACM, New York, NY, USA, 4097–4106. https://doi.org/10.1145/2556288.2557051

[23] Antti Salovaara, Antti Lindqvist, Tero Hasu, and Jonna Häkkilä. 2011. The phone rings but the user doesn't answer: unavailability in mobile communication. In *Proceedings of the 13th International Conference on Human Computer Interaction with Mobile Devices and Services (MobileHCI '11)*. ACM, New York, NY, USA, 503–512. https://doi.org/10.1145/2037373.2037448

[24] Seiichi Serikawa and Lifeng Zhang. 2011. Proposal of a Touch Panel Switch with the Function of Bending and Addition - One of a New User Interface. In *Proceedings of the 2nd International Conference on Instrumentation, Communications, Information Technology, and Biomedical Engineering*. IEEE, USA, 8–13. https://doi.org/10.1109/ICICI-BME.2011.6108580

[25] Mihail Terenti, Cristian Pamparau, and Radu-Daniel Vatavu. 2024. The User Experience of Distal Arm-level Vibrotactile Feedback for Interactions with Virtual versus Physical Displays. *Virtual Reality* 28, Article 84 (2024), 21 pages. https://doi.org/10.1007/s10055-024-00977-2

[26] Emily N. Ussery, Geoffrey P. Whitfield, Janet E. Fulton, Deborah A. Galuska, Charles E. Matthews, Peter T. Katzmarzyk, and Susan A. Carlson. 2021. Trends in Self-Reported Sitting Time by Physical Activity Levels Among US Adults, NHANES 2007/2008-2017/2018. *Journal of Physical Activity and Health* 18, S1 (2021), S74–S83. https://doi.org/10.1123/jpah.2021-0221

[27] Radu-Daniel Vatavu. 2012. User-defined gestures for free-hand TV control. In *Proceedings of the 10th European Conference on Interactive TV and Video (EuroITV '12)*. ACM, New York, NY, USA, 45–48. https://doi.org/10.1145/2325616.2325626

[28] Radu-Daniel Vatavu and Laura-Bianca Bilius. 2021. GestuRING: A Web-based Tool for Designing Gesture Input with Rings, Ring-Like, and Ring-Ready Devices. In *Proceedings of the 34th Annual ACM Symposium on User Interface Software and Technology (UIST '21)*. ACM, New York, NY, USA, 710–723. https://doi.org/10.1145/3472749.3474780

[29] Radu-Daniel Vatavu and Ştefan Gheorghe Pentiuc. 2008. Interactive Coffee Tables: Interfacing TV within an Intuitive, Fun and Shared Experience. In *Proceedings of the 6th European Interactive TV Conference (EuroITV '08)*. Springer, Heidelberg, 183–187. https://doi.org/10.1007/978-3-540-69478-6_24

[30] Mihira Wanninayake and Richard O. Sinnott. 2019. An Exploration of Commuter Travel Time Through Social Media Analytics on the Cloud. In *Proceedings of the 6th IEEE/ACM International Conference on Big Data Computing, Applications and Technologies (BDCAT '19)*. ACM, New York, NY, USA, 43–51. https://doi.org/10.1145/3365109.3368790

[31] Lin Yang, Chao Cao, Elizabeth D. Kantor, Long H. Nguyen, Xiaobin Zheng, Yikyung Park, Edward L. Giovannucci, Charles E. Matthews, Graham A. Colditz, and Yin Cao. 2019. Trends in Sedentary Behavior Among the US Population, 2001-2016. *JAMA* 321, 16 (04 2019), 1587–1597. https://doi.org/10.1001/jama.2019.3636

[32] Ionuţ-Alexandru Zaiţi, Ştefan Gheorghe Pentiuc, and Radu-Daniel Vatavu. 2015. On Free-Hand TV Control: Experimental Results on User-Elicited Gestures with Leap Motion. *Personal and Ubiquitous Computing* 19, 5-6 (2015), 821–838. https://doi.org/10.1007/s00779-015-0863-y