

Fingerhinter Takes Center Stage: User Experience Insights from Informal Encounters with a Finger-Augmentation Device

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Abstract—Conventional feedback methods for delivering mobile notifications primarily resort on the visual, auditory, and tactile channels, readily accommodated by smartphones, smartwatches, glasses, and armbands. Contrary to this mainstream, we are interested in this work in information delivered through the user’s body, designed for the kinesthetic channel, which involves dedicated devices that can actuate specific body parts, e.g., putting the index finger into states of hyper-extension at custom angles and duration. Given the novelty of this feedback type, situated at the intersection of body augmentation, extended reality, and wearable computing, very few studies have reported on the user experience of kinesthetic notifications, especially in real-world contexts of use. In this paper, we report on observations collected during a two-day open-public science fair, where we presented “Fingerhinter,” our finger-augmentation device designed for kinesthetic feedback, to a large and heterogeneous audience. More than one hundred people, aged five to fifty years old, engaged with Fingerhinter and provided valuable insights about their experience of wearing and using it. Out of these participants, a subgroup of twenty also completed the UMUX-Lite questionnaire to formally evaluate their user experience. Additionally, we report on the participants’ feedback regarding suitable notification types for kinesthetic feedback delivery as well as potential applications that could benefit from the integration of kinesthetic feedback into smart interactive wearables.

Index Terms—Wearables, finger-augmentation devices, kinesthetic feedback, Extended Reality, Sensorimotor Realities

I. INTRODUCTION

Notifications are ubiquitous in a connected world where mobile users have increasing access to a diversity of smart mobile and wearable devices, of which one major function is keeping users updated with digital content of various sources, from current news to personal health and activity to social media. Conventional methods employed to deliver notifications primarily employ visual, auditory, and vibrational cues. Contrary to this mainstream, our goal in this paper is exploring a less studied modality for implementing notifications that uses the kinesthetic channel in the larger context of designing digital proprioception for devices, environments, and users [2].

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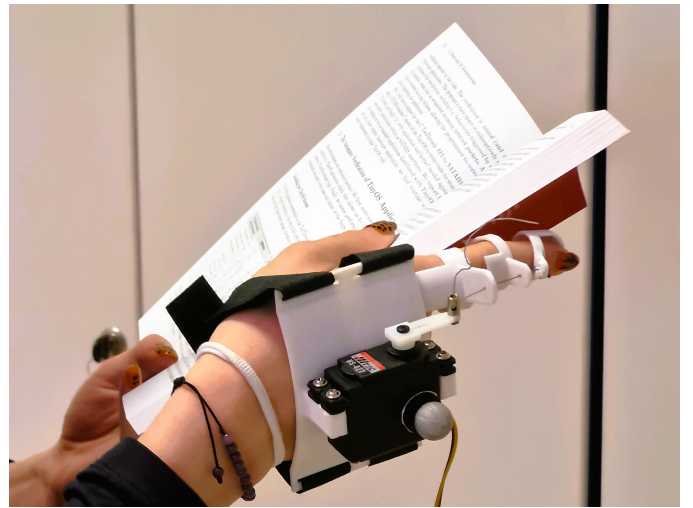


Fig. 1. Fingerhinter [1], our index-finger-augmentation device for kinesthetic feedback, consists of a servomechanism that pulls the index finger into controlled states of hyper-extension at specified angles. In the example portrayed in this photograph, Fingerhinter could enhance reading by providing feedback related to the action from the book or by implementing a kinesthetic bookmark, i.e., finger extension when the user reaches a specified page.

While user behavior and preferences for conventional feedback modalities have been well-documented [3]–[8], emerging output modalities subsumed under the paradigm of on-body interaction [9] and non-natural interaction [10] require dedicated examination to understand user experience (UX).

On-body interaction represents an emerging computing paradigm in which the human body is repurposed as a generic input/output platform [11]–[13]. In this paradigm, computer devices compete for the cognitive, sensory, and motor resources of the human body, occasionally affecting user agency and, sometimes, facilitating digital symbiosis with the user. In this context, kinesthetic feedback is perception of position and movement of one’s body parts originating from receivers in the body joints and muscles [14], [15]. By leveraging kinesthesia through body actuation, user agency may be temporarily affected during the delivery of a notification [1],

which is transmitted not to the user's body, but through the body. Fingerhinter [1], portrayed in Figure 1, is our finger-augmentation device, used in this work to elicit the UX of notifications delivery through movements of the index finger.

Kinesthetic feedback generated by a computer device designed to be worn on the user's body can be characterized from the perspective of extended reality (XR) applied to the sensorimotor level, i.e., an instance of Sensorimotor Realities (SRs) [16]. Since Fingerhinter delivers kinesthetic feedback through controlled index-finger hyper-extensions, it addresses a different sensory landscape compared to conventional XR devices and technology, coupled with actuation of the finger. Consequently, understanding the UX of such a modality for the delivery of digital content, which acts as an extension beyond the physical reality of the body, forms the goal of this work. Our contribution is represented by an analysis of observations collected during a two-day open-public science fair, where we presented Fingerhinter to a heterogeneous audience. We report insights from users' informal encounters with kinesthetic feedback technology, and suggest opportunities for future work in this direction at the intersection of body augmentation, extended reality, and wearable computing.

II. RELATED WORK

The scientific literature contains many reports on the implementation of kinesthetic feedback involving wearable devices, for which a variety of technologies has been considered, including electric motors [17]–[19], electric muscle stimulation (EMS) [20], electromyography (EMG) [21], EMS and EMG in conjunction [22], [23], and shape memory alloys (SMAs) [24], among others. The majority of work on kinesthetic feedback has focused on applications within virtual environments, gaming, medical contexts, or various simulation scenarios. Fingerhinter [1] was used as a test bench for demonstrating kinesthetic feedback to unveil participants' preferences for corresponding notifications as well as to assess their usability in various contexts of use. In the next section, we present more details about Fingerhinter, the device used for this work.

III. FINGERHINTER, A FINGER-AUGMENTATION DEVICE FOR KINESTHETIC FEEDBACK

In the following, we briefly describe technical and engineering details of Fingerhinter [1], the wearable device used in this work for implementing finger-level kinesthetic feedback.

A. Technical details

Fingerhinter has the capability to put the index finger into a state of hyper-extension, which represents a "fingerhint" [1], during which user agency is temporarily bypassed; see Figure 1 from the first page for a photograph. Fingerhinter is composed of a Hitec HS-422 servomechanism [25] (3.3kg/cm maximum torque and 0.21s/60° speed at 4.8V) that provides the necessary power for index-finger hyper-extensions, attached through a nylon thread to a series of supports placed on each phalanx of the finger. This configuration ensures stability and comfort as power is distributed across the entire finger

and each phalanx is individually supported. The platform and supports were created using PLA (Polylactic Acid) through 3D printing using the Fused Filament Fabrication (FFF) technology, which ensures that the constituent parts of Fingerhinter are lightweight. The platform and servomechanism are affixed to the dorsal part of the hand using Velcro straps, ensuring a secure fit for various hand sizes. The servomechanism is controlled by an Arduino MKR WIFI 1010 [26]. For power, we used a series of four GP ReCyko Pro 1.2V 2000mAh rechargeable batteries with the voltage stabilized at 5V through a boost converter; for more details, we refer readers to [1].

B. Kinesthetic feedback

A fingerhint represents kinesthetic feedback produced by a finger-augmentation device, such as Fingerhinter [1], in the form of actuation that puts the finger into a series of n consecutive states of hyper-extension. A fingerhint can be fully specified with a mathematical formalization of θ and τ , as follows: $\{(\theta_i, \tau_i) \in [0^\circ, 45^\circ] \times (0, \infty), i = 1..n\}$, where θ_i represent the finger extension angles at the metacarpophalangeal (MCP) joint, given an upper limit of 45° according to human anatomical limitations [27], [28], and τ specifies the dwell time during which the finger is kept in a specific hyper-extension of θ . A simple fingerhint can be described as $\gamma_1 = \{(25^\circ, 250\text{ms})\}$, i.e., the device produces a 25° finger hyper-extension at the MCP joint, pauses for 250ms, and releases the finger, which returns to its previous state. More complex fingertips comprise several states of hyper-extension, for example: $\gamma_2 = \{(40^\circ, 500\text{ms}), (20^\circ, 500\text{ms}), (30^\circ, 250\text{ms})\}$. In this example, the finger is put into a state of 40° hyper-extension for $\tau_1=500\text{ms}$; subsequently, the finger transitions to the next state, represented by 20°, for an additional $\tau_2=500\text{ms}$; in the end, the finger returns to its initial state.

IV. INFORMAL ENCOUNTERS WITH FINGERHINTER

We presented Fingerhinter to a large and heterogeneous audience during an open-public science fair, with the goal of collecting observations about the user experience of fingerhints represented by notifications delivery through the body.

A. Audience

Fingerhinter was tested by a diverse group of over 100 individuals, ranging in age from 5 to 50 years old. Due to the unexpectedly high popularity of the device, a considerable number of individuals were waiting in line to test it. Of this audience, a sample of 20 people (7 male, 13 female, ages between 12 and 45 years old, $M=24.9$, $SD=11$ years) participated in a more formal evaluation by providing detailed feedback about the device and answering specific UX questions.

B. Setting

We arranged a booth to exhibit Fingerhinter at a science fair (see Figure 2 for photographs) and implemented the following protocol for greeting visitors to our booth. First, we provided an explanation of Fingerhinter's purpose functionality. For the visitors that wished to try the experience of



Fig. 2. Visitors of a science fair experiencing kinesthetic feedback delivered by Fingerhinter, our finger-augmentation device.

kinesthetic feedback for themselves, we attached Fingerhinter to their dominant hand and calibrated the length of the wire to accommodate different hand sizes. Once Fingerhinter was comfortably in place, various fingerhinters (see Subsection III-B for examples) were demonstrated. After the visitors confirmed they understood the purpose of the device and experienced kinesthetic notifications, we elicited them for feedback about several aspects of Fingerhinter, structured in the form of a short UX questionnaire for fast administration in such a setting. The questionnaire comprised demographic information (age and gender), the two items of UMUX-Lite¹ (Usability Metric for User Experience) [31] rated on 7-point Likert scales, and the following two open-ended questions: “What type of notifications would you prefer to receive through Fingerhinter?” and “For what purposes would you utilize Fingerhinter?”.

V. RESULTS

We found that the mean UMUX score was 76.7 (SD=15.0) on a scale from 0 (low) to 100 (high usability); see Figure 3, left. Considering that Fingerhinter was merely a prototype with a prominent and conspicuous form factor, we consider this score to be quite commendable. Furthermore, this result reveals a good usability perception after just one first, informal encounter with kinesthetic feedback technology, strengthening empirical results obtained through in-lab evaluations [1]. Specifically, Catană and Vatau [1] reported a mean UMUX score of 62.5 from a thorough evaluation conducted with 21 participants across many UX dimensions. In response to our first open-ended question about suitable notification

types to be delivered with Fingerhinter, we elicited a total of 26 suggestions, which we grouped into six categories: text messages (9/26=34.6%), phone calls (6/26=23.1%), social networks (5/26=19.2%), reminders (2/26=7.7%), calendar events (2/26=7.7%), and alarms (2/26=7.7%); see Figure 3, right. Responses to our question about potential applications and use cases for Fingerhinter included VR, video games, and health rehabilitation. Many of the visitors who tried Fingerhinter described a distinctive sensation, somewhat unusual, yet overall enjoyable and non-discomforting.

VI. TOWARDS INTELLIGENT NOTIFICATION DELIVERY ON THE KINESTHETIC CHANNEL

We designed Fingerhinter as a platform to assess usability perceptions and collect user feedback about the distinctive experience of kinesthetic notification delivery at the index-finger level. In future work, we envision various application scenarios where interactive systems leverage kinesthetic feedback for intelligent notifications that adapt to their users’ context. To resume the example from Figure 1, let us consider the activity of reading a book being enhanced by kinesthetic feedback delivered on the fingers and hands used to hold and manipulate the book. As the user picks up the book, Fingerhinter could begin signaling, through subtle index-finger extensions, proximity to the page where the user stopped reading last time, and eventually culminate in a noticeable pull of the finger upon reaching that page—i.e., a kinesthetic bookmark. Also, while the user is reading, Fingerhinter could deliver finger movements that match the intensity of the action described on the current page, contributing to an increased immersive experience where the user’s body is effectively involved in

¹UMUX-Lite is the shorter version of UMUX and SUS [29], for which prior work [30] reported good correlation scores.

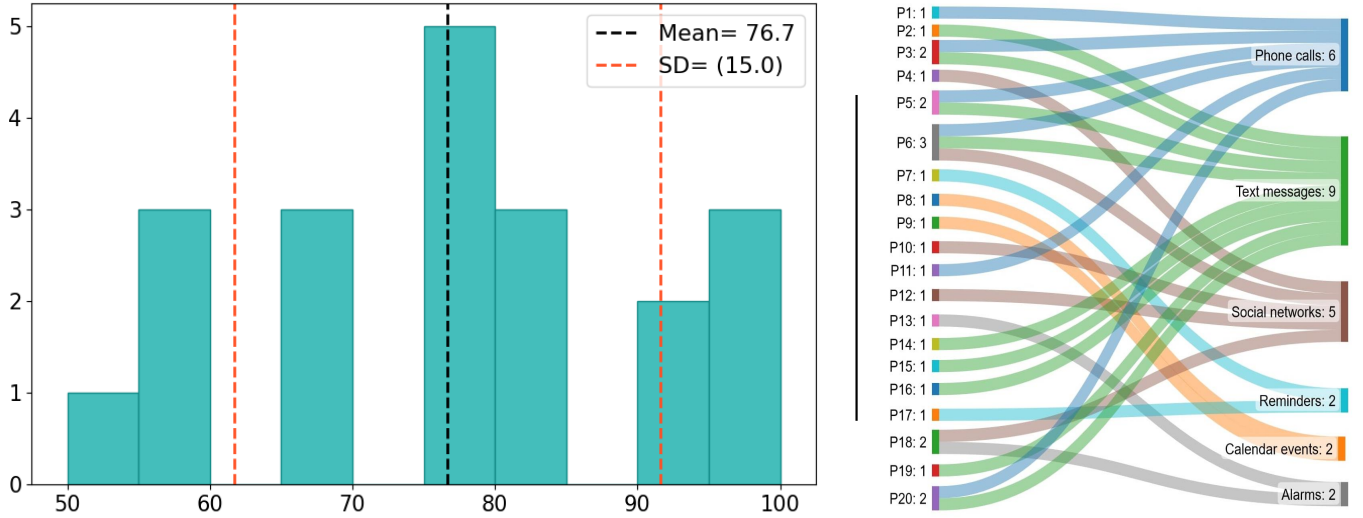


Fig. 3. Left: distribution of the UMUX-Lite scores obtained from an evaluation involving a sample (N=20) of visitors to our booth. Right: expressed preferences for notifications associated with kinesthetic feedback collected during our evaluation.

the reading process—i.e., a kinesthetic reading experience. Finally, Fingerhinter could serve to deliver notifications from external sources, such as alerting the user about a missed phone call, filtered based on an intelligent assessment of the user’s interruptibility level, e.g., by balancing notification urgency with the user’s engagement in their current activity. To intelligently deliver fingerhinter in such situations, the wearable device can leverage IMUs and torsion sensors to infer the level of interruptibility from the user’s activity. For instance, by using the data from IMU sensors integrated in off-the-shelf wearable devices, CNN-LSTM models can identify activity [32]. Furthermore, adjusting the pattern and intensity of fingerhinter according to the user’s context can lead to more personalized notification experiences. If the reading activity transitions to storytelling in VR, fingerhinter could further enhance the kinesthetic reading experience by delivering a more realistic perception of the story action and/or objects constituting the action with which the user interacts in the virtual environment. In such a scenario, intelligent adaptation would involve appropriate management of notifications originating from the real world, e.g., a missed phone call, to a user immersed in a virtual environment. Such an experience, positioned in-between worlds, can be characterized with the formalism of augmented journeys [33] and necessitates design on a dedicated UX layer, “switch,” with distinctive characteristics. On that layer, transition design between worlds specifies the kinds of journeys possible in the notification delivery space. Such explorations represent interesting future work at the intersection of body augmentation, artificial intelligence, extended reality, and wearable computing.

VII. CONCLUSION

We reported evaluation results of a finger-augmentation device designed for kinesthetic feedback at the index-finger level, which we obtained in the wild, outside the laboratory, by involving a heterogeneous group of potential end users.

The unconventional form factor of our device, its unusual and distinctive behavior, and the novel feedback modality employed to deliver information through one’s body attracted a large audience. We were able to confirm findings about the UX of kinesthetic feedback, previously obtained in the controlled setting of a research laboratory, from casual first encounters with kinesthetic notification delivery technology. This result can lead to many future work opportunities for interactive wearables implementing kinesthetic feedback. Notably, by leveraging intelligent adaptation using machine learning models trained on motion data to infer user activity, kinesthetic notifications could be highly personalized. The notifications would match the user’s context, in either physical, virtual, mixed, or extended reality, with patterns and intensity levels aligning with the inferred user’s interruptibility level. Such an approach would lead to highly tailored, context-aware experiences in receiving notifications through the body and, thus, intelligently engaging the body with digital experiences.

REFERENCES

- [1] A.-V. Catană and R.-D. Vatavu, “Fingerhinter: Understanding users’ perceptions of and preferences for on-finger kinesthetic notifications,” in *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, ser. CHI ’23. New York, NY, USA: ACM, 2023, pp. 1–17. [Online]. Available: <https://dx.doi.org/10.1145/3544548.3581022>
- [2] R.-D. Vatavu and O.-A. Schipor, “Formalizing digital proprioception for devices, environments, and users,” in *Proceedings of the 12th International Symposium on Ambient Intelligence. Lecture Notes in Networks and Systems*, vol. 483, ser. ISAmI ’21. Cham: Springer, 2022.
- [3] T.-C. Lin, Y.-S. Su, E. H. Yang, Y. H. Chen, H.-P. Lee, and Y.-J. Chang, “Put it on the Top, I’ll Read it Later”: Investigating Users’ Desired Display Order for Smartphone Notifications,” in *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, ser. CHI ’21. New York, NY, USA: Association for Computing Machinery, May 2021, pp. 1–13. [Online]. Available: <https://doi.org/10.1145/3411764.3445384>
- [4] A. Mehrotra, V. Pejovic, J. Vermeulen, R. Hendley, and M. Musolesi, “My Phone and Me: Understanding People’s Receptivity to Mobile Notifications,” in *Proceedings of the 2016 CHI Conference on Human*

- Factors in Computing Systems*, ser. CHI '16. New York, NY, USA: Association for Computing Machinery, May 2016, pp. 1021–1032. [Online]. Available: <https://doi.org/10.1145/2858036.2858566>
- [5] M. Pielot, K. Church, and R. de Oliveira, “An in-situ study of mobile phone notifications,” in *Proceedings of the 16th international conference on Human-computer interaction with mobile devices & services*, ser. MobileHCI '14. New York, NY, USA: Association for Computing Machinery, Sep. 2014, pp. 233–242. [Online]. Available: <https://doi.org/10.1145/2628363.2628364>
 - [6] M. Pielot and L. Rello, “Productive, anxious, lonely: 24 hours without push notifications,” in *Proceedings of the 19th International Conference on Human-Computer Interaction with Mobile Devices and Services*, ser. MobileHCI '17. New York, NY, USA: Association for Computing Machinery, Sep. 2017, pp. 1–11. [Online]. Available: <https://doi.org/10.1145/3098279.3098526>
 - [7] A. Sahami Shirazi, N. Henze, T. Dingler, M. Pielot, D. Weber, and A. Schmidt, “Large-scale assessment of mobile notifications,” in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ser. CHI '14. New York, NY, USA: Association for Computing Machinery, Apr. 2014, pp. 3055–3064. [Online]. Available: <https://doi.org/10.1145/2556288.2557189>
 - [8] M. Terenti and R.-D. Vatavu, “Measuring the user experience of vibrotactile feedback on the finger, wrist, and forearm for touch input on large displays,” in *Extended Abstracts of the 2022 CHI Conference on Human Factors in Computing Systems*, ser. CHI EA '22. New York, NY, USA: Association for Computing Machinery, 2022, pp. 286:1–286:7. [Online]. Available: <https://doi.org/10.1145/3491101.3519704>
 - [9] J. Bergström and K. Hornbæk, “Human–Computer Interaction on the Skin,” *ACM Computing Surveys*, vol. 52, no. 4, pp. 77:1–77:14, Aug. 2019. [Online]. Available: <https://doi.org/10.1145/3332166>
 - [10] R.-D. Vatavu, “From natural to non-natural interaction: Embracing interaction design beyond the accepted convention of natural,” in *Proceedings of the 25th International Conference on Multimodal Interaction*, ser. ICMI '23. New York, NY, USA: Association for Computing Machinery, 2023, p. 684–688. [Online]. Available: <https://doi.org/10.1145/3577190.3616122>
 - [11] C. Harrison, S. Ramamurthy, and S. E. Hudson, “On-body interaction: armed and dangerous,” in *Proceedings of the Sixth International Conference on Tangible, Embedded and Embodied Interaction*. Kingston Ontario Canada: ACM, Feb. 2012, pp. 69–76. [Online]. Available: <https://dl.acm.org/doi/10.1145/2148131.2148148>
 - [12] C. Harrison, H. Benko, and A. D. Wilson, “OmniTouch: wearable multitouch interaction everywhere,” in *Proceedings of the 24th annual ACM symposium on User interface software and technology*, ser. UIST '11. New York, NY, USA: Association for Computing Machinery, Oct. 2011, pp. 441–450. [Online]. Available: <https://doi.org/10.1145/2047196.2047255>
 - [13] D. Tan, D. Morris, and T. S. Saponas, “Interfaces on the go,” *XRDS: Crossroads, The ACM Magazine for Students*, vol. 16, no. 4, pp. 30–34, Jun. 2010. [Online]. Available: <https://dl.acm.org/doi/10.1145/1764848.1764856>
 - [14] E. V. Evars, “Sherrington’s concept of proprioception,” *Trends Neurosci.*, vol. 4, pp. 44–46, 1981. [Online]. Available: [https://doi.org/10.1016/0166-2236\(81\)90016-3](https://doi.org/10.1016/0166-2236(81)90016-3)
 - [15] U. Proske and S. C. Gandevia, “Kinesthetic senses,” *Comprehensive Physiology*, vol. 8, no. 3, pp. 1157–1183, 2018. [Online]. Available: <https://doi.org/10.1002/cphy.c170036>
 - [16] R.-D. Vatavu, “Sensorimotor realities: Formalizing ability-mediating design for computer-mediated reality environments,” in *Proceedings of the IEEE International Symposium on Mixed and Augmented Reality*, ser. ISMAR '22, 2022, pp. 685–694. [Online]. Available: <https://dx.doi.org/10.1109/ISMAR55827.2022.00086>
 - [17] S. B. Schorr and A. M. Okamura, “Fingertip Tactile Devices for Virtual Object Manipulation and Exploration,” in *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, ser. CHI '17. New York, NY, USA: Association for Computing Machinery, May 2017, pp. 3115–3119. [Online]. Available: <https://doi.org/10.1145/3025453.3025744>
 - [18] K. Minamizawa, S. Fukamachi, H. Kajimoto, N. Kawakami, and S. Tachi, “Gravity grabber: wearable haptic display to present virtual mass sensation,” in *ACM SIGGRAPH 2007 emerging technologies*, ser. SIGGRAPH '07. New York, NY, USA: Association for Computing Machinery, Aug. 2007, pp. 8–es. [Online]. Available: <https://doi.org/10.1145/1278280.1278289>
 - [19] B. Son and J. Park, “Haptic Feedback to the Palm and Fingers for Improved Tactile Perception of Large Objects,” in *Proceedings of the 31st Annual ACM Symposium on User Interface Software and Technology*, ser. UIST '18. New York, NY, USA: Association for Computing Machinery, Oct. 2018, pp. 757–763. [Online]. Available: <https://doi.org/10.1145/3242587.3242656>
 - [20] P. Lopes, A. Ion, W. Mueller, D. Hoffmann, P. Jonell, and P. Baudisch, “Proprioceptive Interaction,” in *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, ser. CHI '15. New York, NY, USA: ACM, Apr. 2015, pp. 939–948. [Online]. Available: <https://doi.org/10.1145/2702123.2702461>
 - [21] Y. Koike, K. Nakakoji, and Y. Yamamoto, “Tele-kinesthetic interaction: using hand muscles to interact with a tangible 3D object,” in *ACM SIGGRAPH 2006 Emerging technologies*, ser. SIGGRAPH '06. New York, NY, USA: Association for Computing Machinery, Jul. 2006, pp. 33–es. [Online]. Available: <https://doi.org/10.1145/1179133.1179167>
 - [22] M. Rietzler, G. Haas, T. Dreja, F. Geiselhart, and E. Rukzio, “Virtual Muscle Force: Communicating Kinesthetic Forces Through Pseudo-Haptic Feedback and Muscle Input,” in *Proceedings of the 32nd Annual ACM Symposium on User Interface Software and Technology*, ser. UIST '19. New York, NY, USA: Association for Computing Machinery, Oct. 2019, pp. 913–922. [Online]. Available: <https://doi.org/10.1145/3332165.3347871>
 - [23] J. Nishida, S. Kasahara, and K. Suzuki, “Wired muscle: generating faster kinesthetic reaction by inter-personally connecting muscles,” in *ACM SIGGRAPH 2017 Emerging Technologies*, ser. SIGGRAPH '17. New York, NY, USA: Association for Computing Machinery, Jul. 2017, pp. 1–2. [Online]. Available: <https://doi.org/10.1145/3084822.3084844>
 - [24] T. Nakao, K. Kunze, M. Isogai, S. Shimizu, and Y. S. Pai, “FingerFlex: Shape Memory Alloy-based Actuation on Fingers for Kinesthetic Haptic Feedback,” in *Proceedings of the 19th International Conference on Mobile and Ubiquitous Multimedia*, ser. MUM '20. New York, NY, USA: Association for Computing Machinery, Nov. 2020, pp. 240–244. [Online]. Available: <https://doi.org/10.1145/3428361.3428404>
 - [25] “HS-422 Deluxe Standard Servo.” [Online]. Available: <https://hitecercd.com/products/servos/analog/sport-2/hs-422/product>
 - [26] “Arduino MKR WiFi 1010.” [Online]. Available: <https://store.arduino.cc/products/arduino-mkr-wifi-1010>
 - [27] C. E. Lang and M. H. Schieber, “Human Finger Independence: Limitations due to Passive Mechanical Coupling Versus Active Neuromuscular Control,” *Journal of Neurophysiology*, vol. 92, no. 5, pp. 2802–2810, Nov. 2004. [Online]. Available: <https://www.physiology.org/doi/10.1152/jn.00480.2004>
 - [28] “Wrist/Hand Active Range of Motion (AROM) | Basic Assessment.” [Online]. Available: <https://www.physiotutors.com/wiki/wrist-hand-active-range-of-motion/>
 - [29] J. Brooke, “SUS: A ‘Quick and Dirty’ Usability Scale,” in *Usability Evaluation In Industry*. CRC Press, 1996.
 - [30] S. Borsci, S. Federici, S. Bacci, M. Gnaldi, and F. Bartolucci, “Assessing User Satisfaction in the Era of User Experience: Comparison of the SUS, UMUX, and UMUX-LITE as a Function of Product Experience,” *International Journal of Human-Computer Interaction*, vol. 31, no. 8, pp. 484–495, Aug. 2015. [Online]. Available: <http://www.tandfonline.com/doi/full/10.1080/10447318.2015.1064648>
 - [31] J. R. Lewis, B. S. Utesch, and D. E. Maher, “UMUX-LITE: when there’s no time for the SUS,” in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ser. CHI '13. New York, NY, USA: Association for Computing Machinery, Apr. 2013, pp. 2099–2102. [Online]. Available: <https://doi.org/10.1145/2470654.2481287>
 - [32] A. Alevizaki, N. Pham, and N. Trigoni, “Invited paper: Hierarchical activity recognition with smartwatch imu,” in *Proceedings of the 24th International Conference on Distributed Computing and Networking*, ser. ICDCN '23. New York, NY, USA: Association for Computing Machinery, 2023, p. 48–57. [Online]. Available: <https://doi.org/10.1145/3571306.3571390>
 - [33] C. Pamparău and R.-D. Vatavu, “The user experience of journeys in the realm of augmented reality television,” in *Proceedings of the 2022 ACM International Conference on Interactive Media Experiences*, ser. IMX '22. New York, NY, USA: Association for Computing Machinery, 2022, p. 161–174. [Online]. Available: <https://doi.org/10.1145/3505284.3529969>