Interdisciplinary research on designing smart braille gloves for visually impaired people using MXene and embroidery techniques

Miha Kim[a], Hwansoo Shin[b], Mee Jekal[†]

Applied Art, Hanyang University, Seoul, South Korea[a], Human-Tech Convergence, Organic Nano Engineering, Hanyang University, Seoul, South Korea[b], Clothing & Textiles, Hanyang University, Seoul, South Korea[†]

Introduction Concerning the life quality of visually impaired people (VIP) have emerged as significant facets in inclusive society. According to WHO (2014), approximately 43.3 million people are visually impaired, and the population is growing worldwide, and the half of these cases classified as low vision (World Health Organization, 2014). Braille provides VIP a way to access important daily information, including communication, reading, and professional correspondence (Martiniello, Haririsanati, & Wittich, 2022). However, VIP often face challenges in learning and using Braille, and even with existing equipment, including smart technologies, as of aesthetical and emotional discomfort beyond usability and accessibility. Therefore, this study proposed a wearable device designing to aid VIP who are not familiar with braille and/or who have challenged in learning and using braille within design thinking process. The research questions for this study are 1) What are the challenges VIP face when acquiring Braille information, and what are the design needs for users to develop assistive devices? 2) What is the total solution of design from formation to sensing effect concerning users' emotional and aesthetical comfort based on design factors?

Literature review Braille comprises coded characters arranged in a consistent configuration of six raised dots within a cell-based spatial unit. This character system is widely employed by VIP, as it facilitates the storage and transmission of information through tactile perception, rather than relying on visual cues (Saikot & Sanim, 2022). Despite recognizing the importance of Braille for academic pursuits, job performance, accessing information, and restoring self-esteem, the complexity of learning Braille often leads to educational difficulties in finding suitable educational institutions. (Ardiansah & Okazaki, 2020). Additionally, acquired visual impairment where individuals are more accustomed to the visual system or experience reduced tactile sensitivity due to comorbidities, only a small fraction of individuals can effectively utilize Braille (Haga & Ito, 2021; Saikot & Sanim, 2022).

Research framework Interdisciplinary research team (Applied Art, Clothing & Textiles, Organic Nano Engineering) conducted mixed-method research following double diamond module (Discover, Define, Develop, and Deliver) of the design thinking process (DTP); thinking from a user-centric perspective, designing the problem-solving process, and deriving solutions, and it can be considered as a series of steps in practical projects from divergent and convergent thinking (Brown, 2008). First, we conducted qualitative interviews to analyze the Braille utilizing method and needs of VIP and derived design factors.

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Subsequently, we conducted experiments with appropriate embroidery methods and connection structures using MXene-coated yarn to enable Braille recognition, based on the design factors. In the final step, we proposed the design of a wearable glove for Braille recognition, incorporating these findings.

Design Process & Results

Understanding users for defining design factors (Discover & Define process): We conducted qualitative interviews participants who were interested in their appearance, actively participated in social and economic activities (N=7, 20-30s, Korea) with semi-structured questionnaires (Creswell, 2013) for understanding VIP users' Braille using behavior. According to three level coding analysis, data showed there was significant needs for a wearable Braille recognition device that can enhance sensing effect for recognizing Braille as a fashionable item. The design factors for developing wearable Braille recognition device are; a) portability, b) aesthetics, c) universality, d) tactility, and e) manageability. The total solution based on design factors was developing wearable smart Braille gloves using MXene and simplified details. The MXene, ceramic nanomaterials with high conductivity and mechanical properties, selected as the most appropriate sensing material with highest scores among conducted properties in wearable products including conductive polymers, graphene, carbon nanotubes (CNTs), metals, and MXene.

Prototype development with testing (Develop process): Two experiments were conducted to develop a precise pressure sensor capable of recognizing Braille composed of six small raised dots. First, conductive fibers were created by coating mercerized cotton fibers with MXene. Second, prototypes were produced using a simple cross-stitch method and a modified French knot method to explore embroidery techniques that yield high recognition rates for the pressure sensor. In the second experiment, two types of prototypes were developed: one with connected sensors and the other with independent sensors (Connected vs. Independent Sensing) to derive patterns suitable for high-performance, precise wearable pressure sensors. As a results, we developed independently complex embroidery structure with enhanced sensing performance for wearable capacitive pressure sensor through design engineering. Our strategy gave insights to fields that required highly localized and independent sensing, such as braille recognition.

Improved design (Deliver process): The improved braille glove was designed based on experimental results and participants' satisfaction. Firstly, wearable technology was implemented to facilitate the convenient carrying and usage of the glove for individuals with visual impairments in their daily lives. While ensuring the fundamental readability of braille using the index finger, a glove structure was suggested to enhance its portability. Subsequently, precise pressure sensors being capable of recognizing braille were affixed to the index finger section. Through two experiments, appropriate embroidery techniques and connection structures for fabricating wearable pressure sensors using MXene material were validated and subsequently integrated into the glove. The MXene coated cotton thread, utilized in the pressure sensors, exhibits conductivity and is linked to a virtual computer responsible for processing braille information. To minimize the visibility of the dark thread stitches, the thread was embedded with stitches acrossing palm and wrist.

Conclusion The interdisciplinary research was conducted within DTP to address real-world problems from a user-centric perspective, fostering positive social impact. We found technologies like smart cameras pose considerable challenges for user adoption through qualitative interview. Our proposed wearable glove, equipped with a high-performance Braille recognition sensor, is designed to enhance the psychological and aesthetic satisfaction of VIP. This design allows them to maintain their existing Braille reading methods with enhancing performance while avoiding social stigma through its universal design and technical support. The significance of this research lies in the potential for future collaborative research with software design converting Braille's surface information into computer data.

References

Ardiansah, J. T., & Okazaki, Y. (2020). The design and prototyping of braille to speech application as a self-learning support media for visually impaired person. I*n 2020 4th International Conference on Vocational Education and Training (ICOVET).* 224-228.

Brown, T. (2008). *Design thinking*. Harvard Business Review, 1-10.

Creswell, J. W. (2013). *Qualitative inquiry & reseach design : Choosing among the five approaches (3th ed.)*. Thound Oaks, CA: Sage.

Haga, N., & Ito, S. (2021). Wearable braille reader. *IEEE 10th Global Conference on Consumer Electronics (GCCE)*, 849-852.

Martiniello, N., Haririsanati, L., & Wittich, W. (2022). Enablers and barriers encountered by working-age and older adults with vision impairment who pursue braille training. *Disability and Rehabilitation, 44*(11), 2347-2362.

Saikot, M. M. H., & Sanim, K. R. I. (2022). Refreshable braille display with adjustable cell size for learners with different tactile sensitivity. *IEEE Transactions on Haptics, 15*(3), 582-591.

World Health Organization. (2014). *Visual impairment and blindness*. Retrieved from https://www.who.int/mediacentre/factsheets/fs282/en/