

Enhancing visibility of street cleaners' smart clothing uniform for their safety and sustainable usability

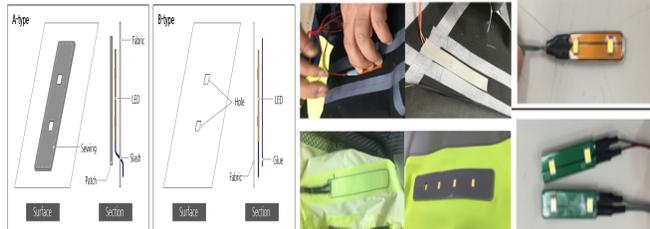
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Introduction: The 81% of street cleaners' occupational death or injury occurred during nighttime due to vehicle-related traffic accidents between 2015 and 2017 in South Korea. It caused by low visibility of street cleaners' job characteristics and environments (Park, Lee, & Lee, 2020). According to Lee (2010), high visibility uniform using both embedded luminescence and retro-reflective function are effective for street cleaners to enhance their safety during nighttime. However, current existing safety vest with luminescence embedded Light-Emitting Diodes (LED) in the market has several problems in using sustainably with users' satisfaction (Han & Jeon, 2012). Therefore, the purpose of the research is to explore users' needs in using embedded luminescence, and to develop a smart uniform for street cleaners to enhance visibility for their safety and sustainable usability. The research question is how can design researchers enhance the visibility of street cleaners' uniform for their safety and sustainable usability? **Literature review and research framework:** Smart clothing means embedded technologies on clothing to change colors, patterns, or shapes, etc. Especially, many researchers use LED, electro luminescence, optical fibers and fabrics, organic light-emitting diodes, or other display technologies in changing colors, patterns, or lighting. (Koo, Dunne, & Bye, 2014). However, there are several problems in sustainable using and aesthetical satisfaction for smart clothing (An & Lim, 2020; Han & Jeon, 2012). To develop smart clothing uniform for street cleaners' safety and sustainable usability with users' integrated satisfaction, Jordan's pleasurable design process - functionality → usability → aesthetic pleasure - was used as research framework (Jordan, 1998). **Methods:** This research conducted mixed-methods research methods: 1) pre-interview (N=5) and pre-survey (N=100) for defining problems, 2) experiment to test sustainable using for technology embedded smart clothing in machine washing, 3) post-survey (N=79) for checking user's satisfaction on safety, sustainable usability, and aesthetical aspect. After defining problems of using existed smart uniform for street cleaners, design researchers develop prototypes to test user's sustainable usability and their safety with their aesthetic satisfaction upon IRB approval. **Prototypes development process:** Researchers considered three main aspects to solve problems (weak durability in machine washing, and dazzling issue due to LED light) of existing LED embedded smart uniform for street cleaners; a) LED protection on machine washing, b) retro-reflective print pattern development for enlarging area without full coverage, and c) changing location of LED. As the first stage, researchers considered LED attaching methods on fabric due to reduce noticeability of users. Two types of attachment were considered; 1) A-type (sewing type)-sewing the outline of LED with layering additional patch on fabric, 2) B-type (adhesion

type)-making small holes inside the fabric to expose LED bulbs only and attaching with adhesive tape (Figure 1). Both A and B types are all durable on washing test, but A type was more suitable for mass production without error in punching. In addition, LED bulb area was separated from PCB (Printed Circuit Board) or intersection of electronic wire connection was broken through 2-



3 times pre-machine washing test. To solve the problems, researchers developed four different solutions; 1) Covering the connection between LED and PCB with heat-shrinkage tube (Polyurethane material), 2) Reducing twist issue with covering heat-adhesive lining (polyester material) on the margin of LED, 3) Decreasing bended area

with short length PCB because the connection between PCB and LED was easily broken when PCB was in diagonal bending, 4) Using hard type PCB for durability.

Figure 1. LED attachment on fabric process with protecting solution

As the second stage, semi-covered retro-reflective print pattern was developed to enhance visibility with retro-reflective effectiveness. The motif was inspired from Korean traditional window frame with the philosophical meaning of ‘protection’ and ‘transmitted light’. The two different window frame motives [(1): Gwigabsal, (2) Sutdaesal] were chosen from participants, and finally, (1) Gwigabsal motif was selected as of printing issue on the corner using with liquid retro-reflective materials on fabric. Additionally, the printed area was converted from line to face to enhance visibility after printing test. As the third stage, LED location on street cleaners’ uniform was tested based on participants’ dazzling issue. To reduce dazzling issue, researchers changed the location of LED (four bulbs) from front side to back side, and only put one bulb indicator LED (users can indicate if the backside LED works or not well) on the front side.

Result and Significance: The prototype was usable sustainably on over 25times (5 times/month x 5 months) machine washing (machine type: Samsung Wa16F7K8MTA01, using neutral detergent, dried within natural environment.) without decreasing brightness and broken issue. Regarding integrated participants’ satisfaction, the 83.5% of participants satisfied with the retro-reflective print and design aesthetically and functionally. Regarding to LED luminescence protection and location, participants responded positively (N=79, Gender=Male 100%, $M_{age} = 50.24$, $M_{experience} = 12.7yrs$): It is helpful to reduce occupational death and injuries (M=3.65, 5-point Likert scale, 1=Strongly disagree, 5=Strongly agree), the brightness of LED is suitable for working on my eyes (M=3.35), the location of LED is suitable for working and safety (M=3.43). Even though this study has many limitations on experimental methods, these results are important for the future design research in developing smart clothing with under-served users’ integrated satisfaction. The significance of the research is to contribute to enhance visibility of street cleaners’ uniform considering safety and sustainable usability.

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