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Designing a solar powered jacket for the day hiker: Application of the apparel design framework and functional, expressive, and aesthetic (FEA) consumer needs model

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Background and Research Purpose. Solar energy has been the most important and a long-term energy source for humanity (Jong-Hyeok & Gilsoo, 2009). To save natural and manmade resources, using solar energy is one of the smart options as the sun is the direct energy with highest potential. Since the major problem of wearable electronics is the necessity to rely on conventional power supplies (e.g., batteries), which are usually heavy with a short lifetime (Jong-Hyeok & Gilsoo, 2009); solar powered energy sources that are flexible and light, can be incorporated into clothing without being a burden to the wearer. Hwang, Chung, and Sanders (2016), found that functional, expressive, and aesthetic (FEA) garment attributes affected user attitudes toward solar powered clothing. Thus, all components of the FEA consumer needs model and apparel design framework (Lamb & Kallal, 1992) are important considerations when designing solar powered apparel. Flexible solar panels have been used in fashion accessories such as backpacks, and hats. Solar powered garments are potentially useful to a range of individuals from the recreational outdoor market to those in the safety industry, such as the military. However, only a few apparel products exist in the marketplace today. Research is needed on the functionality of flexible solar cells to understand how to integrate them into apparel in an expressive and aesthetic manner. Therefore, the purpose of this study was to design a solar powered garment using the FEA model and apparel design framework (Lamb & Kallal, 1992).

Method. Lamb and Kallal's (1992) apparel design framework and FEA model was selected to guide the process of designing a solar powered jacket. The following research steps were undertaken: (1) *Problem identification:* Design problems were identified through focus group interviews and analysis of sample garments. Based on user needs, a list of functional, expressive, and aesthetic design criteria were established, (2) *Preliminary ideas*: Sketching, brainstorming, research, and question-and-answer sessions were used to generate multiple preliminary ideas for meeting the design criteria, (3) *Design refinement*: The developed design ideas were compared to the design criteria. Where conflicts, primarily around number of panels required for specified wattage, were discovered between competing FEA design criteria, priorities were established. Some preliminary ideas were modified, some were discarded, and others were selected for further development, resulting in one idea that could then be tested. (4) *Prototype development*: Multiple garment component prototypes and then for the entire sample garment were created to determine appropriate stitch selections, material handling requirements (e.g. washability), compatibility of shell and interior fabrics, and construction sequencing. Necessary standards for solar panel testing (physical and energy harvesting) took place. (5) *Evaluation*: Prototypes were evaluated according to the established functional, expressive, and aesthetic design criteria, and (6) *Implementation*: The revised product design was then executed.

Results. (1) The identified target consumer group was defined as both female and male college students day hikers, who need a power source. The garment type was selected as gender-neutral jacket for outdoor activities. The most important functional design criteria specific to this solar powered jacket was identified as the requirement for a minimum energy output to power a cell phone. Another key functional design criteria was that appropriate electronic components (wires, etc.) were needed for the solar power to travel from the solar panels to the device. Once energy output level was established at 4.6 Watts the number and size of panels, as well as related electronic equipment needed to achieve this energy output were determined. Additional electronics-related function design criteria established were: (a) wearer safety (e.g. will not overheat/ electric shocks etc.), (b) electronic components must not impede the movement of user, (c) the jacket must be washable, (d) the power source should be in an easily accessible location for the user, and easy removal of the electronic components for washing of the garment. Other functional needs established for the user included: (a) the jacket should protect the wearer from cold wind (warmth), (b) the jacket should provide storage for the user's item, as interviews indicated most day hikers only bring a few things in their pockets, as opposed to wearing a backpack, and (c) the jacket should be compatible with the user's use of a backpack. The most important expressive need identified was visual adaptability. Users wanted to be able to hide the solar panels and have it look like a "normal" jacket, when they were not harvesting energy. Aesthetic needs were: (a) unisex designs, (b) colors in line with current fashion trends, (c) style elements in line with current fashion trends.

(2 &3) Sketches were developed to illustrate potential placements of solar panels, including on the hood, sleeve, and body of the jacket. Preliminary design ideas for meeting the functional criteria of warmth included: (a) wind-resistant Fabric, (b) hood, possibly (detachable), (c) built-up neck, (d) secure closures (Velcro, zippers, buttons etc.), (e) adjustable cuffs (to keep the wind out), (f) waist and hood drawstrings. Multiple pocket types were also discussed to meet functional storage needs.

(4, 5 & 6) The results of machine-washing the attached solar panels resulted in a pleasant aesthetic appearance, as well as no reduction in ability to collect solar power. From these results, it was determined that the solar panels did not have to be removable. Both subjective and objective measurements were used to rate prototypes. Design ideas were eliminated or modified based on the results. The revised product design was produced for further wear and comfort testing.

Implications. The Lamb and Kallal (1992) apparel design framework with FEA consumer needs model was effective in guiding the process for designing and testing a solar powered jacket. The design decision-making process was challenging due to balancing user needs with functional needs of electronic components. Findings may be useful for designers of wearable solar products for other markets and for designers of all types of wearable electronics.

References

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