Understanding Design Preferences and Expectations on Wearable Monitoring Systems for Diabetes

Helen Koo, University of California, Davis, USA
Dawn Michaelson, Karla Teel, and Dong-Joo Kim, Auburn University, USA

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In the United States, diabetes is the 7th leading cause of death and the total cost of diagnosed diabetes increased from $174 billion in 2007 to $245 billion in 2012 (American Diabetes Association, 2015; United States Centers for Disease Control and Prevention-CDC, 2014). Diabetes also leads to severe complications but thousands of people are not aware they have the disease, thus, the individuals with diabetes (CDC, 2014). Early diagnosis of diabetes and self-monitoring is significant to controlling diabetes and for treatment (Clarke & Foster, 2012). Wearable monitoring systems consisting of sensors integrated into clothing have developed substantially over the past decade (Baek, Chung, Kim, & Park, 2012). The purpose of this research was to understand preferences and expectations on wearable e-nose system designs to develop a wearable monitoring system integrated into clothing to measure breath and skin gases from wearers for real-time health monitoring. The results of this research are expected to be beneficial for apparel designers and engineers when developing these wearable monitoring systems.

The literature review was conducted in the development of wearable devices for diabetes focusing on glucose monitoring techniques and wearable devices and non-invasive e-nose system for diabetes. Monitoring blood glucose techniques can be divided into three main approaches: 1) invasive methods that are chemical and biochemical methods or using a glucometer; 2) minimally invasive methods such as iontophoresis, and microdialysis probe sensor; and 3) non-invasive methods like the wearable monitoring system discussed in this study (Andrew et al., 2012). To design and develop a wearable monitoring system, understanding consumer needs and wants is critical to succeed in the market and be worn by users.

After receiving an approval from an institutional review board (IRB), an online survey tool (qualtrics.com) was used to understand potential consumer preferences and expectations on designs of wearable monitoring systems for potential users. Based on the results, design strategies of the wearable monitoring system will be defined regarding use-contexts, clothing types, design concepts, design factors, and design details. These will impact the location of sensors on clothing, sensor sizes, sensor types, cutting-seam lines, seam types, fabric types, and versatile designs for long-term monitoring. A total of 194 participants, who did and did not have diabetes, included 72 males (37.1%) and 122 females (62.9%), with an age range from 19 to 56 years with a mean age of 21 years. The online questionnaire consisted of three sections. Section 1 asked the respondent if they have diabetes. If they did, then additional questions concerning diabetes type, length of time, medications, and monitoring were asked. Those that did not have diabetes proceeded to Section 3. Section 2 addressed monitoring of blood glucose levels by asking how often they monitor, type of equipment, satisfaction, along with difficulties and

improvements to their current monitoring system. Section 3 focused on the sensor-integrated design factors including levels of importance and preferences, which were placed on a 10 point-Likert scale (1=very marginal to 10=very important). Additionally, three open-ended questions were used to voice their suggestions or comments that may have not previously been discussed in the questionnaire. Data were imported into SPSS version 22.0 software and analyzed in descriptive statistics such as mean, SD, percentages. The qualitative data were color-coded, major themes were extracted, and descriptive analyses were conducted.

The important design factors for the wearable monitoring system for diabetes were safety (*m*=9, SD=2.11), data accuracy (*m*=9, SD=2.04), reasonable price (*m*=8, SD=2.10), portable (*m*=8, SD=2.11), movements (*m*=9, SD=2.11), and durability (*m*=9, SD=2.11). The preferred and expected characteristics of sensors are selectively indicated for majorly selected design options: sensor longevity were 1-2 years (38.7%), less than 1 year (25.8%), 3-5 years (22.2%), and more than 5 years (13.3%); sensor sizes were 3-5cm (41.8%), 1-2cm (40.2%), less than 1cm (10.8%), and more than 5cm (7.2%); sensor types were detachable patch (53.5%), accessory type (40.2%), and permanently attached or other (6.3%); locations of sensor were arm or hand (34.5%), mid-under bust area (22.2%), and shoulder area (16.5%); color were various color options to match with clothing (46.9%), beige or brown (14.9%), and black (13.4%); sensor shapes were round (51.5%), square (22.7%), and rectangular (12.9%); costs of sensors were $100-199 (40.7%), and $50-99 (28.9%); and delivery methods of data were smart phone apps (88.1%). In the open-ended questions, the sensor design suggestions were making them into accessories instead adding to garments such as ring, jewelry, or watch (34.3%); and unnoticeable designs were preferred (53.1%). The ease of transmission of data to a device such as using text, securing data, and to a physician accessible system were also important design factors (36%).

The results will be beneficial for apparel designers and wearable technology developers of diabetic products to consider the important design factors, preferences and expectations on design. Retailers and marketers can also consider what aspects need to be emphasized for these types of wearable monitoring system for different types of promotions.

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