Parent-Centered Design: A Preliminary Usability Study on Newborn Home Cardiac Monitoring

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Abstract. Current measurement techniques in the medical field, such as electrocardiography (ECG) and pulse oximetry, are critical for monitoring the cardiovascular health of newborns [1]. Although there are devices on the market capable of measuring these signals, they are often not designed for use with newborns. This study conducted a preliminary usability test of four cardiovascular monitors for use with a newborn model. The findings indicated that users prefer a simple, wireless device that can be securely attached to a child to minimize movement. Additionally, they value a guided process and straightforward, user-friendly software. Understanding user preferences can facilitate developing an affordable, at-home monitoring device tailored for newborns which in turn may enhance early detection and management of congenital heart diseases (CHDs).

Introduction. CHDs are structural abnormalities of the heart present at birth. These conditions are often identified shortly after birth, allowing for timely intervention and treatment. However, CHDs are still the leading cause of mortality due to birth defects [2]. The most common diagnostic tools for CHDs in newborns include ECG, chest X-rays, echocardiograms, and pulse oximetry. In addition to these primary diagnostic methods, more comprehensive evaluations can be conducted to monitor heart rhythm. Such tests can involve the use of a Holter monitor, implantable event recorder, and pacemaker [1]. Despite the variety of diagnostic tools available, CHDs can still remain undiagnosed and untreated until the patient's health is significantly affected, even into adulthood [2]. Screening for these conditions typically occurs in clinical settings, which not all individuals have easy access to. Moreover, the high cost of some of these diagnostic tests poses a barrier, particularly in underserved areas [3]. Consequently, there is a pressing need for an affordable, accessible monitoring device that can facilitate the early detection and management of CHDs in newborns. Such a device could reduce morbidity, mortality, and healthcare costs associated with these diseases. Currently, the market offers limited options for at-home monitoring of newborns, and these are often cost-prohibitive and limited in functionality. This study aims to evaluate users' experience interacting with commercial and research-grade cardiovascular monitoring devices. The insights gained will be used to develop an optimized cardiovascular monitoring device tailored for the newborn population that integrates essential functions and features while ensuring user comfort and ease of use.

Methods. After IRB approval at Mississippi State University, user experience research was conducted with 3 subjects (1 female). The inclusion criteria were planning to have a child within the next year or having had a child in the past three years. This ensured that the subjects were in a state of mind of being a parent during the study. Prior to the study, minor modifications were made to some of the devices to make them more compatible with a baby model. User experience was evaluated through interviews with the subjects and in-lab qualitative usability testing employing the think-aloud method. Participants were introduced to the functions and features of four different cardiac monitors (Fig. 1, top row) including a pulse oximeter (PO5, Shenzhen Livenpace Technology Co., Ltd., China), an ECG recorder (HHM1, Shenzhen Livenpace Technology Co., Ltd., China), and two different sensors enabling seismocardiogram (SCG) and gyrocardiogram (GCG) measurements (Shimmer3 Ebio, ShimmerSensing, Ireland; and BWT901CL, WitMotion Shenzhen Co., Ltd., China). Although SCG and GCG signals have not yet been clinically translated, they hold significant potential for providing information about the mechanical activity of the heart and could be utilized in future remote cardiovascular monitoring systems [4, 5]. Thus, it is essential to recognize that the Shimmer3 and WitMotion are research devices and are not approved for clinical use. Similarly, the

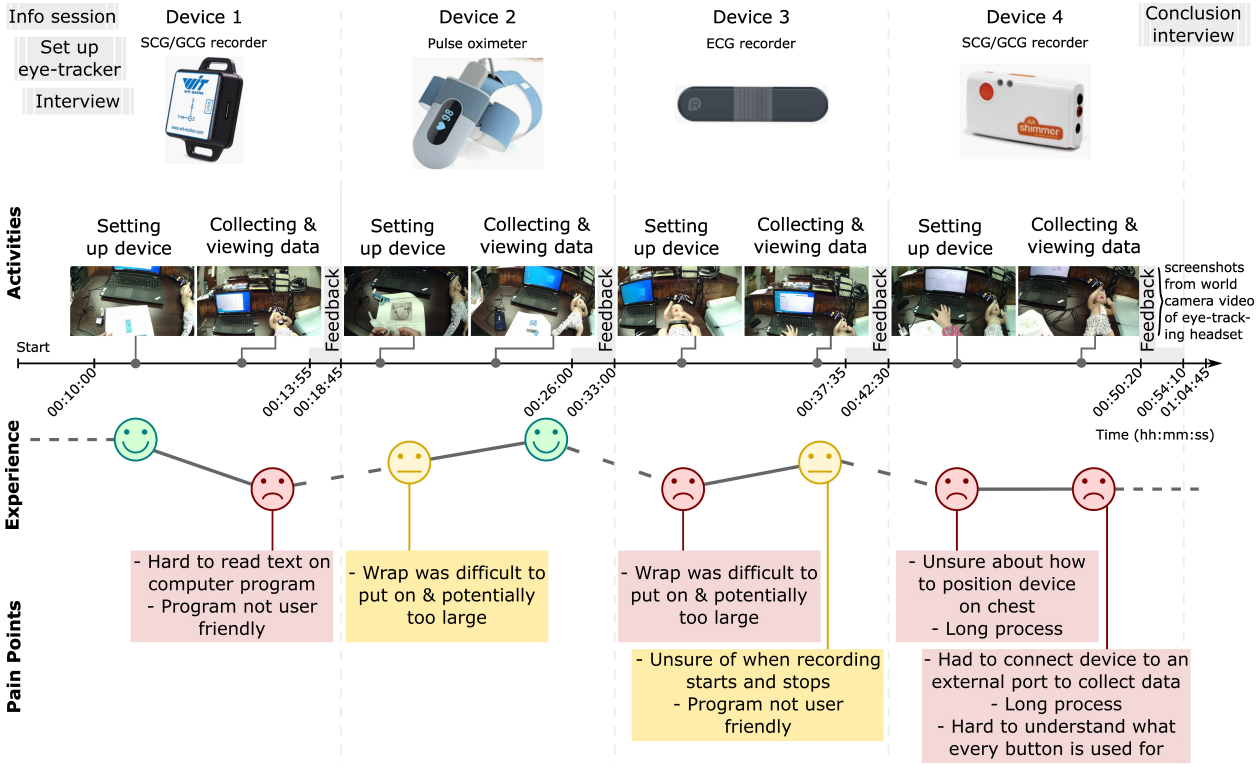

Figure 1. (Top row) Cardiac monitors utilized in the study to assess user experience. From left to right: BWT901CL, (WitMotion Shenzhen Co., Ltd., China), PO5 (Shenzhen Livenpace Technology Co., Ltd., China), ECG recorder (HHM1, Shenzhen Livenpace Technology Co., Ltd., China), and Shimmer3 Ebio (ShimmerSensing, Ireland). (Bottom panel) Journey map of Subject 1 with screenshots from the eye tracking headset and pain points expressed by the subject. The time axis is not to scale.

HHM1 ECG recorder and PO5 pulse oximeter are at-home monitoring devices that have not been subjected to clinical testing. Participants were then instructed to use the devices on the baby model, following the provided instruction sheets. The tasks of the usability test included setting up the device, using the software program, and utilizing the device's features. They were also instructed not to ask questions to maintain a consistent experience for all subjects by relying solely on the provided materials. During this process, the subjects' audio was recorded, and a Pupil Core eye-tracking headset (Pupil Labs GmbH, Berlin, Germany) was employed to gain deeper insights into their experience, exploring their pain points, opinions, and mental models. After testing each device, subjects were asked a series of questions to further understand their experience. The collected data was analyzed using journey mapping and affinity mapping techniques to comprehensively evaluate the user experience.

Results and Discussions. The collected data provided valuable insights into user preferences and comfort levels with home monitoring devices. While the current sample size is insufficient for drawing general conclusions, this study functions as a feasibility study to refine the approach for future interviews with a larger and more diverse population. It is important to note that the aim of this study was not to determine which device performs best among the four evaluated; rather, it sought to identify the design factors that influence users' choices between devices. As such, evaluating the clinical accuracy and precision of these devices was beyond the scope of this study and was not considered when analyzing user preferences.

Two of the three subjects had prior experience using at-home monitoring devices on themselves or others. Overall, participants expressed a preference for a simple and efficient process for both attaching the device to their child and collecting data. Specifically, they appreciated the use of a wireless device. They also

preferred that the device be securely attached to the chest, considering the potential movement of the child. Participants felt most comfortable when notifications guided them through the process, such as device's LED lights indicating when the recording had started and ended. Additionally, they found it helpful when the device had icons to direct them to the correct position for recording on the chest.

The user journey map in Fig. 1 illustrates the experiences and emotions of Subject 1 while interacting with different devices. During the setup phase, Subject 1 expressed the most comfort with devices featuring a simple setup process and a singular multi-functional button, such as devices 1 and 2. Conversely, the subject was least comfortable with devices that could not be securely attached to the body and were too large for comfort. Additionally, Subject 1 favored software programs that required a minimal number of steps. Device 2 was particularly noted for its ease of use, featuring a streamlined process for data collection and viewing, thanks to its minimalist design and user-friendly software. The subject found the use of multiple components and the lack of clear indication of when recording started and stopped to be the most challenging when collecting data. Moreover, taking multiple steps to view the data was considered difficult, and the subject stated that remembering all the steps would be problematic.

All participants preferred software programs with large, clear text and a simplistic setup. Two of the three participants also expressed a desire for improved information visualization, seeking results presented in graphical form and receiving user-friendly analysis. They appreciated devices with simple features, such as a single, accessible multi-functional button. Participants felt most comfortable with a single-piece device and valued the ability to interact with the device via a digital screen. Moreover, they were drawn to devices with soft colors and rounded edges, indicating a preference for these design elements when choosing a device for their child.

Conclusion. The findings identified key features and functions that enhance the user experience with newborn home cardiac monitors. Users preferred a simplistic process that prioritizes the comfort of their child. These insights will guide the development of a new device tailored to these preferences. Further studies are necessary to ensure that users consistently feel comfortable using the device on their children.

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