EVALUATING VALUE SENSITIVE DESIGN OF HUMAN ORTHOTIC DEVICES

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

Recent events from bias in facial recognition software to social movements against higher carbon footprint devices have brought to light how our values are a crucial factor in the reception and creation of technologies. Now more than ever, individuals, companies, and groups are realizing the importance of taking societal and personal values and norms into serious consideration during the design process. Value sensitive design (VSD) is an approach for foregrounding human values in the technical design process (Friedman & Hendry, 2019). With the aim of ensuring that the most important values we hold to inform the products and systems we design. In the field of biomedical devices, where users have an intimate relationship with the technology they use, this integration of values and what is important to the user with the designed product is particularly relevant. This integration between user and device is especially important in orthotics, orthotics are externally applied devices used to help a person go about their daily life. They are used in a wide variety of applications from helping people walk to play sports to get out of bed, etc. Patients rely on their orthotics daily to go about normal actions, so designing them in a way that fit the user's lifestyle and values is critical. This paper surveys several case studies to analyze and discern their alignment with VSD practices, identifying gaps in the design process and areas of success and failure. It then attempts to apply the tenants of VSD to see if VSD's methodology can capture those fail points to determine whether or to what extent value sensitive design is the solution to current issues in orthotics design. With the goal of ultimately answering the question: "What design practices might we use to design orthotics that maximize the wellbeing of the user?". Friedman and Hendry's paper on the value and future of value sensitive design will serve as a framework for VSD principles and a lens by which to examine past products and the design processes utilized (Friedman & Hendry, 2019).

Scholarly Conversation

Value sensitive design is a framework for helping the moral and ethical values we hold to, what is most important to us, inform the design process for the betterment of human beings and the natural world. VSD does this through providing theory, method, and practice for accounting for human values throughout the design process (Friedman & Hendry, 2019). Friedman & Henry define the 'value' in value sensitive design as what a person or group of people consider important in life, with an emphasis on moral and ethical considerations. Value sensitive design posits that humans shape and influence the tools they design, and in turn those technologies shape culture and the human experience. One implication of this is that "technology is neither good nor bad; nor is it neutral" (Kranzberg, 1986, p. 545). Hence, Friedman and Kranzberg believe that there is great importance in being intentional about what values are embodied in technology and go on to influence culture and the world.

To analyze this circle of influence, Friedman proposes a tripartite methodology of conceptual, empirical, and technical investigations to analyze the value implications of design. Conceptual investigations involve asking questions to explore the central issues under consideration, examples include: "Who are the stakeholders?" and "What values will be implicated by a given design?". For example, in their analysis of trust in web design, Friedman, Kahn, and Howe (2000), propose a philosophically based definition of trust (Friedman et al., 2000). They propose that people trust a system or person when they are vulnerable to harm from them, yet believe those others would not harm them even though they could, and act based off that belief. Think of a trust fall, you could fall flat on your back if the person you were trusting did not catch you, but you trust they will and fall anyway. From this conceptualization Friedman et al were able to clearly establish a definition of trust and work. Empirical investigations seek to address similarly value focused questions such as "Are there differences between what people say compared with what people do?" utilizing all the quantitative and qualitative data available through the scientific method. Technical investigations look at technologies as a whole and their impact on how people live and behave, often with a retroactive focus / lens. Examples of questions to

answer include, “What features of a technology facilitate or impair certain kinds of human behaviors?”. Looking for the application of these investigations will provide a useful method for the analysis of the following case studies on orthotics design.

To apply all this theoretical framework to the real word requires practical methods and procedures. The following case studies will be investigated for some of the most common structured VSD methods: stakeholder analysis, value-oriented semi-structured interviews, and stakeholder tokens. Stakeholder analysis involves identifying individuals, groups, etc. that may be impacted by a technology, with a distinction between those who are directly and indirectly affected (Friedman & Hendry, 2019). An example of the usefulness of this method can be seen in a study done on the impact of having a real time nature scene visible in an office workspace. While initially focused on the productivity of office workers, an early stakeholder analysis identified an important group of indirect individuals, “those individuals who would walk through the scene and have their images captured and displayed in the inside offices” (Friedman et al., 2006, p. 15). Without this analysis, this important indirect stakeholder group and the privacy consideration associated would have been missed.

Value-oriented semi-structured interviews make use of semi-structured interview questions in order to elicit stakeholders’ understandings, views, and values regarding technology (Friedman & Hendry, 2019). Questions are designed to provoke stakeholders to evaluate and assess a technology in various ways and their reasoning behind said judgments (e.g. “Why?”, “How well did it fit?”). An application of value-oriented semi-structured interviews can be seen in the development of mobile phone parenting technologies by Czeski. Through interviewing parents and children, the team confirmed their hypothesis regarding the importance of privacy to these groups, and discovered that the level of concern varied greatly depending on the type of information (e.g. location services vs mood kid is feeling). This in turn directed the team to investigate the most important areas of concern from the beginning (Czeskis et al., 2010). Stakeholder tokens is a practical tool for the identifying stakeholders and examining the interactions between them. Typically, the application of this tool involves using physical tokens to

represent stakeholder groups, in order to facilitate the identification of direct and indirect groups and better represent relationships between parties.

The described methods originate from common motives core to value sensitive design: (1) A proactive orientation toward influencing design, early in and throughout the design process. (2) Carrying critical analyses of human values into the design and engineering process. (3) Enlarging the scope and significance of human values (Friedman & Hendry, 2019). As the cases are examined for VSD in practice, the motives behind the processes followed will also be an important factor to consider.

Case Study: User Centered Design of Wrist Driven Orthoses

In the design of orthotics, intentionality and focus on the values involved and the wellbeing of the user is particularly needed. Wrist-driven orthoses (WDOs) are devices used by individuals with spinal cord injury to improve hand function. Current designs focused purely on the utility of the hand movement are heavy, uncomfortable, and time-consuming to fabricate (Portnova et al., 2018). Faculty and students at the Department of Mechanical Engineering at the University of Washington set out to solve this problem through the application of 3D printing technology and a focus on having user feedback inform the design process (Portnova et al., 2018). The authors state that "While functionality is the primary goal of many assistive technologies, aesthetic appeal and comfort levels of a prescribed device are critical for many users and have a great impact on device acceptability" (Portnova et al., 2018, p. 13). The design team uses user centered design as their guiding framework, while NOT the same as value sensitive design, an analysis of this study will prove useful in discovering what methods of VSD are implemented in this s strategy and their effectiveness.

Portnova et al. (2018) begin their project by interviewing patients with spinal cord injury to discover what symptoms of their injury are most important, finding that "approximately 75% of these individuals state that they would prefer to regain hand function to any other lost abilities" (p. 1). From the

outset the team has a proactive orientation towards having what is important to the patients influence their design process. Through a technical investigation of other hand orthoses and the hurdles to adoption / pain points felt by users, the team highlights ease of use, function, and dissatisfaction with device appearance as major points of concern for patients. Portnova et al. (2018) goes on to describe customization as a potential solution to these issues, due to its flexible ability to cater to specific patient criteria and physiology and identify 3D printing as a potential solution to the hurdles involved with customization. From the beginning the team prioritizes the heart of value sensitive design, what is most important to the user, through conceptualization and a retrospective look at other technologies.

Portnova et al. (2018) state that one of the two core tenants of their design approach is a focus on "(2) iteratively testing the design of a 3D-printed WDO on hand function with SCI users" (p. 4). In collaboration with local orthotists the team outlined wearability, aesthetics, fit/adjustability, functionality, weight, customizability, durability, and modularity as the driving evaluators and goals of their project. While items such as wearability, aesthetics, and fit clearly align with what is important to the patients, the criteria do lack any explicit examination of the values involved. To test the ease of fabrication of the team's 3D printed WDO, six P&O students were given assembly instructions and pre-fabricated components. Members of the research team observed the P&O students and noted which parts of the assembly process they struggled/succeeded with. This practice applies one of the key methods of value sensitive design, stakeholder analysis. In this case observing indirect stakeholders, as the students doing the testing will not be end users for the technology but will be influential in its development. The observations noted informed revisions to the design and assembly instructions. Once a revised design had been reached, the team began user testing with real patients with spinal cord injuries.

After custom fitting and designing implants for each test subject, the patients performed a series of quantitative tests with and without the WDO. In addition to the quantitative data, Portnova et al. (2018) asked a series of questions and recorded user feedback on the devices, "These comments were audio-recorded and transcribed to identify common themes and suggestions. The user-suggested modifications

were incorporated into the design for further testing" (p. 7). This method of user focus and feedback collection employs the same tactics as a value-oriented semi-structured interview, a value sensitive design method for incorporating user responses in order to understand the values enforced and elicited by a technology. The success of this method can be seen in the concluding comments left by the test patients. While the quantitative results were mixed, all of the users had a positive impression of the devices, Portnova et al. (2018) notes "For example, one user noted that the "WDO makes the performed action a lot more duplicable [whereas] without the device, [he needed] to figure out a new way [to perform the same action] each time" (p. 11).

Case Study: Orthotics Design Processes Analysis

In the design of orthotics, companies overwhelmingly focus on their own device goals and requirements, leaving user input and feedback as an afterthought. This often leads the creation of a new orthotic to be purely an engineering design problem. Duante and co. investigate this state of the industry and propose a better way, asserting that "The design process should consider the physical, mental and psychological traits of its intended users" (Duarte et al., 2017, p. 1). The authors seek to develop a novel design process that prioritizes these other important factors, factors central to the value sensitive design process. This section examines the team's proposed processes and their alignment with VSD in order to help illuminate where facets of VSD are most sorely needed in the biomedical field and where they are being successfully implemented.

In the introduction to the study, Duarte cites "Nadeau et Pailhes stated that the objective of designing products and systems lies on the search to satisfy the users' needs" (p. 1). Just as in the study on WDOs, this central motivation is in line with the primary goal of value sensitive design. As the team here actually works to develop a new framework for developing articular medical devices, the success and

hurdles of their methodology will provide an interesting comparison to the defined methods of VSD. Duarte goes on to cite Langeveld, who states that "the design intents to enrich cultures and to respond to people demands, improving the life quality and creating different lifestyles [5]" (p. 1). The lack of any reference to the value sensitive design framework is striking given the alignment of the goals proposed from the outset. In the development of the case for their proposed method, Duarte et al. (2017) conduct technology investigations on existing orthotic development processes, concluding that the lack of adaptation in processes "may result in movement constraining or discomfort, which in a great number of cases leads to cessation of its [the device's] use. Additionally, the lack of adaptation to the user and/or user needs may also have an impact in terms of social factors, which may psychologically constrain some patients" (p. 1). While bringing to light some practical issues with current processes, the team does not dig deeper at the values or motives involved. If VSD were applied to their process, it could help elicit the deeper issues and values causing and influencing these surface issues. Asking questions such as "What social values / norms are important to users of external medical devices?" and "How might we design devices to better adhere / fit into a patient's lifestyle and routine?" would be helpful in focusing this process on the user's wellbeing.

Duarte et. al reiterate and cement their alignment with the VSD goals through their focus on user centered design and its benefits, citing that "McClelland and Suri stated that human-centered design can be defined as a focus on the critical human issues throughout the designing and development process and also the inevitable trade-offs between human, commercial and technical issues, which should be made in a balanced way" (p. 376). In developing their design methods, Duarte et al. (2017) identify the importance of stakeholders, stating specifically that "the correct definition of stakeholders and their intervention phase is a key factor for the successful of the final product" (p. 376). They go on to provide a thorough analysis of the relevant stake holder groups in the product development and usage of orthoses, and use this to inform their approach to the design process. This approach employs the stakeholder tokens method of value sensitive design, identifying and examining the interactions between stakeholders, in a forward

looking lens. To move from these groups to the beginning stages of design, the team examines other user centered design strategies, carrying out a conceptual investigation to discover common themes and trends. Here the focus of the authors on the practicality and concrete aspects of the process become clear, as they analyze the stages of design, yet take no time to investigate the motivations and niches present behind them. This shift becomes more apparent as Duarte et al begin to lay out their own design strategy, defining the user's needs as "usage significant moments referring to the most critical/substantial situations during the utilization of the device" (p. 380). Beginning and ending their methods section with ascribing these moments to fully satisfying the user's needs. In short, after investigating other design processes and what is important to the user, the team concludes that critical motions of an external medical device, such as the motion of standing up for a patient with a knee brace, will be the focus of their design process. While an important practical consideration, this approach takes no account of the user as a whole person, with feelings, values, routines, and other desires. Instead reducing the focus of their proposed process to satisfying a physical motion.

The team begins with an apparent focus on prioritizing the value sensitive design core of answering "what is most important to us", but in practice falls back to considering little more than the engineering criteria. This dichotomy between the design team's vision and practice spurs several questions regarding the hurdles present in successfully implanting value sensitive design in product development: "Where do disconnects between designer intent, and outcome most often originate from?", "What structures or processes can and are being used to successfully implement values into the design process?", "Where do Duarte and team depart from these proven processes?".

Conclusion

The studies examined support the usefulness of value sensitive design methods, the similarity between VSD and user centered design, and raise important questions regarding its implementation. From the beginning of the study on WDOs conducted by Portnova et. al, the application of VSD methods is clear. Of particular note is the central focus on what is important to the stakeholders, and their application of both stakeholder analysis and semi-structured interviews. The positive results of these approaches are promising, given the testimonies of the users, and support the further implementation of these VSD methods in the design of orthotics. The success of these VSD methods begs the question as to why value sensitive design itself is not being implemented in orthotics design. Is it due to the age / maturity of the design framework and a simple lack of widespread awareness? Or are there certain elements core to it that make it difficult to implement? These questions pose topics for future study if VSD is to improve the design of orthotics in the best and quickest way possible for the betterment of humans. One area for improvement notable in the WDO case is the lesser focus on the actual values behind the results. Despite mention of comfort and usability, the team does not investigate why these factors are important, and what other ways they may be able to better satisfy the values behind them.

The study on common orthotics design processes and their issues by Duarte et al. quite ironically reveals more issues with the process through their own proposed approach. Clearly if VSD is to be implemented with a true focus on the values of users, a structured mechanism needs to be implemented to iteratively refocus the team on this. As was the case with the research team, it is all too easy for engineers and designers to reduce a complex interpersonal problem down to engineering constraints and functionality metrics. This key hurdle connects back to the lack of the specific and intentional implementation of VSD as a framework in orthotics design and provides further motivation for it. The question it seems is not whether the methods of VSD are helpful in improving the lives of stakeholders, but how might the implantation of VSD be better facilitated across corporations, universities, etc.?

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