Thesis Project Portfolio

Design of a Novel Head Fixation Device for MR Guided Focused Ultrasound Blood-Brain-Barrier-Opening Procedures

(Technical Report)

How Hospital Interior Design Can Be Curated to Reduce Depression, Anxiety, and Stress of Cancer Patients

(STS Research Paper)

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Sociotechnical Synthesis

Countless patients across the world depend on hospitals to provide the best quality of care for a variety of afflictions that differ in degrees of severity. The treatments that hospitals provide are especially crucial for individuals suffering from serious conditions such as those dealing with the presence of tumors or cancers within the body. This portfolio focuses on the results of two individual research projects that follow a similar theme of maximizing patient comfort and mental wellbeing. Specifically, the goal of the technical research project is to design a comfortable head fixation device that can be used for focused ultrasound, or FUS applications, while the science, technology, and society (STS) research project presents evidence urging hospital designers to consider the impact of hospital environment on patient mental health, and in turn, patient physical health. Both projects are centered on a population of patients with serious diagnoses, with the technical project targeting patients with abnormalities in the brain, and the STS topic concentrating more on cancer patients. Treatments for both patient populations are intensive and cause considerable stress to patients, which adds to the stress from a diagnosis itself. For the technical research project, the final product is a headframe which avoids invasive techniques altogether whilst being a mode to effective treatment. The motivation to change the design of current headframes is interrelated with the motivation to change hospital interior design altogether, in that the objective is to reduce overall fear and apprehension towards hospital visits. Ultimately, the STS paper further elaborates on the importance of making hospitals more patient-friendly to improve patient prognoses and to facilitate faster recovery.

In order to understand the need to alter the design of fixation devices, it is first necessary to recognize the function and purpose of FUS. FUS is a non-invasive, early-stage technology utilized in the treatment of many medical disorders. The technology functions by using an acoustic lens to concentrate several intersecting ultrasound beams deep within the body with extreme accuracy (White, 2021). A significant treatment of interest is the opening of the blood-brain-barrier (BBB), where a wider area of opened BBB expands the treatment envelope. The BBB is extremely impermeable, allowing only five

percent of 7,000 small molecule drugs to penetrate the barrier (Konofagou et al., 2012). Thus, BBB opening creates the possibility for several applications, including treatment for severe cancers such as Glioblastoma (Abrahao et al., 2019). To facilitate a BBB opening, a patient's head should be properly secured to the FUS apparatus with a headframe. However, stereotactic frames currently used for FUS were originally designed for radiosurgery, making such frames suboptimal for FUS applications. Current headframes are limited in that they yield smaller treatment areas and do not maximize patient comfort, since four pins have to be screwed into the patient's skull (Bichay & Mayville, 2016). The shortcomings of fixation devices pose a serious challenge towards realizing the full potential of FUS treatment; therefore, an improved fixation device remains a great need in the field. Thus, the proposed technical project deliverable is an improved fixation device for FUS applications.

A cancer diagnosis is an extremely stressful event for people of all ages, even if the cancer is detected at an early stage. Factors such as treatment costs, frequency of hospital visits, and effects of treatment add to the mental toll of cancer patients, making co-morbidities such as depression and anxiety common in these patients (Singer, 2018). Since depression has the potential to worsen cancer prognoses, it is necessary to re-design hospitals so as to contribute to a positive mental state in cancer patients especially given the significant portion of time such patients spend in hospitals. The STS portion of this portfolio, in turn, aims to answer the research question: How can hospital designs be curated to reduce depression, anxiety, and stress of cancer patients to ultimately improve cancer progression and patient quality-of-life (QOL)? To answer this question, the STS paper sets forth design elements and themes that should be incorporated within hospital wards based on scientifically backed research articles and established case studies; these research methods show how certain design components influence patient mental states. This research is analyzed through the lens of the Social Construction of Technology, or SCOT, where patient perceptions of certain design elements are paralleled to how such perceptions impact a patient's mental state. In other words, this paper argues that perceptions have the capability to physically affect patients. It is expected that elements such as greenery, vibrant colors and art should be

incorporated within hospital wards to make a patient feel more at home and happier during hospital visits. Results should inform experts who specialize in hospital interior design to consider the impact of design elements on patient mental health.

Design processes as a whole often require considerable time and thought given to background research before the actual ideation and design phase. Even though the STS paper is more centered around engineering-related thought processes in the context of interior design, its argument reveals the commitment required of designers and engineers to yield a deliverable that effectively solves the problem at hand. The motivation behind the STS topic is partially related to the amount of time and effort spent in consulting with physicians and other experts to gain a basic understanding of the problem before even shifting to ideation of the headframe. Separating the analysis of both research projects would be a disservice to the main idea of the portfolio, which highlights the importance of patient-centered design instead of solutions that solve a problem, yet do not benefit patients. Dual analysis of both the technical and STS topics overwhelmingly affirms the importance of a shifted mindset towards design in the health sciences field without needing to lose sight of creativity in innovation.

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