Senses and Sensors in Dentistry

Biofeedback and Sensory Interventions for Alleviating Dental Anxiety in Patients

By Sarah Pearson

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Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

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Contents

Abstract

One in eight New Zealanders experiences dental anxiety, a phenomenon that persists despite great technological leaps in dentistry that have resulted in virtually painless dental treatment. "Sensors and Senses in Dentistry" used human-centred design and action research methodologies to unpack the complexities of dental anxiety and explore ways of improving patient experiences. The research explored how sensory modulation techniques and biofeedback systems could help alleviate dental anxiety in patients and contribute ways to reduce the cycle of fear, avoidance behaviour and dental problems.

Interviews with patients and dentists helped to make visible the critical causes of anxiety in patients and identify potential solutions for helping patients manage their fear and anxiety. Patients shared they had trouble breathing due to their heightened anxiety. This worsened during invasive dental procedures when breathing became more restricted. Patients complained of feelings of drowning and associated severe panic from breathlessness. Furthermore, patients reported a need to feel listened to and be able to express their concerns to their dental practitioner without judgment. However, time was identified as a barrier for practitioners to properly understand their patient's needs and identify or measure their level of dental anxiety.

As a result, the outcome of this research was a weighted therapy cushion, "A Cushion to Comfort", that combined the therapeutic approach of deep pressure touch (DPT), novel biosensing technology for monitoring anxiety levels, and responsive tactile breathing guidance to calm users. Altogether, the therapy cushion aims to help alleviate anxiety and restore patients' breathing. In addition, it is intended that the therapy cushion may provide practitioners with means of identifying their patient's anxiety pre-treatment and support them to provide more personalised care. The cushion utilised 3D-knitting technology to integrate electrocardiography (ECG) and textiles with a seamless and comforting look and feel.

Positioning of the Researcher

To finish my bachelor's study, I explored the potential for EEG (Electroencephalography) sensors to detect mild traumatic brain damage in rugby players. Mild traumatic brain damage is an 'epidemic' in rugby and a significant health risk for the sport. I created a smart wearable for housing these sensors so players could wear them during a game. This experience taught me how to navigate design problems, such as securing electronics safely on the head while maintaining the appropriate positioning of sensor electrodes to collect usable EEG readings.

Before starting my master's, I completed a summer v with AUT's Institute of Biomedical Technologies (IBTEC). During this time, I worked with another product designer to discover the different avenues in which we could apply ECG (electrocardiogram biosensing) and biofeedback. Our primary focus was on measuring stress, for instance, work-related stress or anxiety. I was especially interested the potential uses of biofeedback and biosensing technologies and the opportunities for their use in healthcare as accurate ways to understand better patients' well-being and support self-regulation of physiological processes such as heart rate.

Over the weeks I worked with IBTEC I became further interested in exploring opportunities for how these technologies may be used to help people with anxiety. Before choosing dentistry as the area of focus for my research, I considered other applications for monitoring the physiological effects of anxiety. For example, in mental health to help those suffering from anxiety disorders. My own experiences and my loved ones' who had accessed mental health services inspired me to follow this direction. I saw how people I loved were affected by ill mental health and knowing I there may be opportunity for me to make a difference inspired me to design in this area of health.

Later, I recognised that, unlike most mental health services, dentistry had limited options to offer patients to reduce their anxiety. Dentistry posed an exciting challenge to develop and implement an outcome for use in a clinical environment with small encounters but reports of high anxiety strongly affecting patients.

Contextual Review

In New Zealand alone, one in eight adults experiences dental anxiety, cited as the fifth most common fear (Sukumaran, 2020; Zinke, 2018). Dental anxiety poses as a significant barrier for patients accessing care, powering a vicious cycle of avoidance, dental problems and shame (see figure 1) (Carlsson, 2015).

In this contextual review I will unpack dental anxiety, its consequences, and its complexities. I will uncover what methods are currently available for managing patients with dental anxiety. Examples of such methods include sensory modulation for managing emotional arousal and biofeedback technology for supporting self-regulation and self-awareness in patients. I will then present my focus for this design research project.

Dental anxiety (used interchangeably with dental fear) identifies patients who experience “excessive dread” and anxiety toward dentistry or present fear in clinical dental settings (Beaton, 2014). Amid those who were identified as dentally anxious in New Zealand (a prevalence of 13.3% of New Zealanders); dental anxiety was higher by 14% among women, lower among those 55 and older, higher by 10% among people of European ancestry, and higher by 10% among those living in the most impoverished neighbourhoods (Sukumaran et al., 2020). Avoidance of dental appointments due to fear and anxiety often results in poorer oral health and increased emergency treatments, which are often more invasive, time-intensive, and costly, exacerbating fear (Appukuttan, 2016). Resulting in a persistent cycle of fear and avoidance (see figure 1). Research suggests a great need to develop better solutions both “clinical and population-level” to dimmish dental anxiety, consequently, creating improving accessibility to care, as well as positively impacting the well-being of individuals in these groups (Sukumaran, :

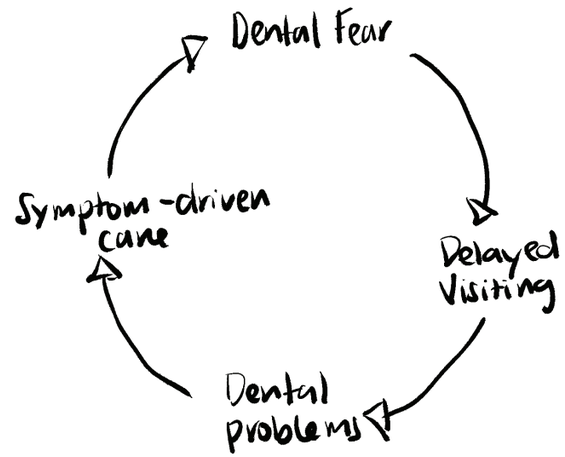


Figure 1. “Vicious cycle of dental fear.” adapted from Appukuttan 2016. “Strategies to manage patients with dental anxiety and dental phobia: literature review.” Clin Cosmet Investig Dent.

Anxiety acts as a “biological warning system preparing the body mentally and physically for danger” (Dempsey, 2016, p. 16). When patients experience dental anxiety this ‘warning system’ is activated in the body, manifesting physically and behaviourally. The signs and symptoms that identify dental anxiety in clinical situations vary and differ from patient to patient (Appukuttan, 2016). For example, a patient may appear restless, tense, and have trouble breathing or swallowing (Appukuttan, 2016) (See Table 1.) for an extended list of potential signs and symptoms). Symptoms become problematic during dental procedures when they cause delays and put the patient and dental operator at risk of injury due to uncooperative behaviour during dental procedures (Obata, 2021). A greater risk of a medical emergency demands a need for the development of better interventions toward reducing risk of injury (Obata, 2021). However, applying a person-centred approach to providing care ensures interventions are focused on supporting patients’ needs (Lee, 2018).

Table 1. Signs and Symptoms of Dentally Anxious Patients and Possible Interventions. Adapted from Appukuttan 2016 p. 38 “Strategies to manage patients with dental anxiety and dental phobia: literature review.” Clin Cosmet Investig Dent.

Signs and Symptoms	*Behaviour*	*Possible interventions*
• Muscle tightness • Unsteady hands • Restlessness • Clearing the throat • Excessive sweating of the hands, forehead, and upper lip (take notice of patients’ sweaty hands during a handshake). • Pulsation of the carotid which is located on the neck and temporal arteries on the forehead. • Depth and speed of respiration. Fast and inconsistent breathing may suggest anxiety. • Firm grip on objects, such as the armrest of the dental chair. • Strong startle response • Frequent Urination	• Hyperactivity • Walking or talking faster • In a hurry • Irritation with delays • Panicky • Blushing • Getting tongue-tied • Nervous habits • Poor memory • Confusing, stumbling over words • Sitting on the edge of the chair, leaning forward, • Rapidly turn pages on magazines • Pacing • Inattentiveness • Excessive worry • Outburst of emotions	• Communication skills, rapport, and trust-building • Relaxation techniques: - Deep breathing - Muscular relaxation • Guided imagery • Biofeedback • Distraction • Exposure therapy • (cognitive therapeutic approach supporting patients to confront fears) • Positive reinforcement. (providing a reward for positive behaviour) • Cognitive behavioural therapy (CBT) (talk therapy to identify negative thoughts and behaviour patterns)

Dental anxiety can be characterised in two ways, as a) pre-treatment or anticipatory anxiety (Hofer, 2016) and b) procedural dental anxiety (e.g., specific stimuli related to dental treatments or fear of dental instruments) (Armfield & Heaton, 2013). A patient experiencing anticipatory dental anxiety may experience dental anxiety days before attending their appointment, making them likely to cancel of delay appointments as a response to their fear (Appukuttan, 2016). The waiting room environment also becomes a place of worry and anticipation for anxious patients. Fux-Noy (2019) found that patients who waited longer for treatment scored a higher dental anxiety score than those seen immediately. Anxious patients seen earlier in the day were less likely to experience long wait times, hence were less anxious before treatments (Fux-Noy, 2019).

Procedural dental anxiety (anxiety while undergoing dental treatment) affects patients in different ways to anticipatory anxiety. A “fear of specific stimuli” being a significant cause of anxiety in this setting (Armfield & Heaton, 2013, p. 392). For example, the sharp clangs of metal on metal from dental instruments, or the sound of the drill (Cartwright, 2010). In a study of patients who avoided treatments, 16.5% feared the drill and 11% the injections (Cartwright, 2010). Interestingly, 22.5% revealed cost as a primary reason for avoidance, while 19.5 % anticipated pain ref (Cartwright, 2010). Therefore, to develop interventions to improve patient experiences and minimise anxiety triggers, the whole patient experience must be considered (i.e., booking appointments to receiving dental treatment).

There can be a variety of reasons that cause dental anxiety in patients. Including a general distrust of dentists based on past lived experiences or learned fear from family members and peers (social learning), or the villainization of dentists in media (Attewell, 1998). Moreover, feelings of loss of control or fear of pain, are potential underlying causes of anxiety in patients (Appukuttan, 2016). Patients with underlying medical conditions and a history of mental health illness are also recognised as high risk for developing dental anxiety (Armfield & Heaton, 2013). Furthermore, pain catastrophizing (fear of pain) and emotional or physical trauma significantly impact pain perception and memory (Engel-Yeger & Dunn, 2011) (Strange & Takarangi, 2015). Pain catastrophizing means, an exaggerated perception of actual or anticipated pain, due to rumination about painful sensations, feelings of helplessness and perceived inability to cope (Engel-Yeger & Dunn, 2011). Consequently, patients may recall a physical or emotional trauma (e.g., dental treatment) as more painful and threatening than the actual real-life event, subsequently exacerbating fear (Strange & Takarangi, 2015).

The New Zealand School Dental Service, established in 1921, provides free dentistry to all school-aged children (Moffat, 2017). During the "Great Depression" in the 1930s and 1940s proper tools and materials for delivering dental treatments were scarce (Cartwright, 2010; Moffat, 2017). The pain from these instruments was an expected and unavoidable consequence. An excerpt from the 1927 New Zealand Dental Journal reads, "Children should be made to realise that a small amount of necessary physical pain must be borne without complaint, and children who make unnecessary fuss must be firmly checked, otherwise the work will be unduly delayed." (Cartwright, 2010, p. 3). Thus, "The Murder House" was coined, a phrase constructed by school children during this era, still resonating in New Zealander adults today (Cartwright, 2010; NZ On Screen, 2022). Since then, methods for delivering care have undergone vast improvements, making most treatments virtually painless. Yet, a generation of adults remember and fear the dentist because of their childhood experiences (Cartwright, 2010; NZ On Screen, 2022).

A comical representation of the phrase 'Murder House' was brought alive in Waka Attewell's short horror film, "The Murder House", released in 1998 (Attewell, 1998) (see figure 2). The film follows a young boy to the dreaded school dental nurse. The dental nurse character is menacing and relentless. The boy escapes his ordeal, and the red dental bib flaps in the wind like a superhero cape as he makes his way back to class (Attewell, 1998). Finally, he confronts his fears and slowly and begrudgingly makes his way back to the dental clinic. Interestingly, the list of comments published after the film's entire length became accessible on NZ Screen's website clearly shows how "The Murder House" still lives on in older adults. For many, "The Murder House" initiated their fear and distrust of the dentist (NZ On Screen, 2022).

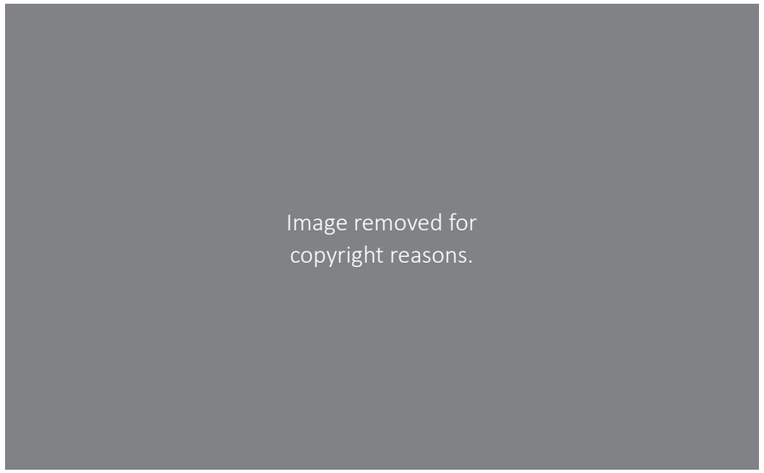


Figure 2. A collage of the scenes from the short film, "The Murder House," by Waka Attewell, depicting the menacing look of the school dental nurse and the terrified young student. Adapted from Attewell 1998 "The Murder House."

Victims of physical or sexual abuse are especially vulnerable to experiencing dental anxiety due to the unique conditions of dentistry (Larijani & Guggisberg, 2015; Wolf, 2020). Such as lying back in the dental chair can elicit feelings of powerlessness and trigger bodily memories related to trauma, i.e., rape or other forms of violating physical abuse (Wolf, 2020) (see figure 3). Abuse victims during dental procedures will display a strong aversion to being touched, discomfort due to the physical proximity with the dentist, an increased gagging reflex and be more reactive to the smell of latex (smell, recognised as a sense closely associated with memory and emotion) (Herz, 2016; Larijani & Guggisberg, 2015; Wolf, 2020). Avoidance behaviour because of trauma negatively impacts oral health, resulting in a higher risk of patients developing gum disease (periodontitis), causing missing teeth, as well as contraction of other oral related infection (e.g., tooth decay) (Larijani & Guggisberg, 2015; Wolf, 2020). Poor oral health not only significantly affects an individual's general well-being but lowers personal satisfaction with dental appearance and is associated with feelings of shame and worthlessness (Wolf, 2020). Wolf (2020) reported dialogue from victims of sexual violence related to dental care: "Now I have kept putting this off, sure to have ten holes. They'll think that I am not a good person. This feeling of having no self-worth came back. I am disgusting; I am worthless. My teeth became me." (Wolf, 2020, p. 319).

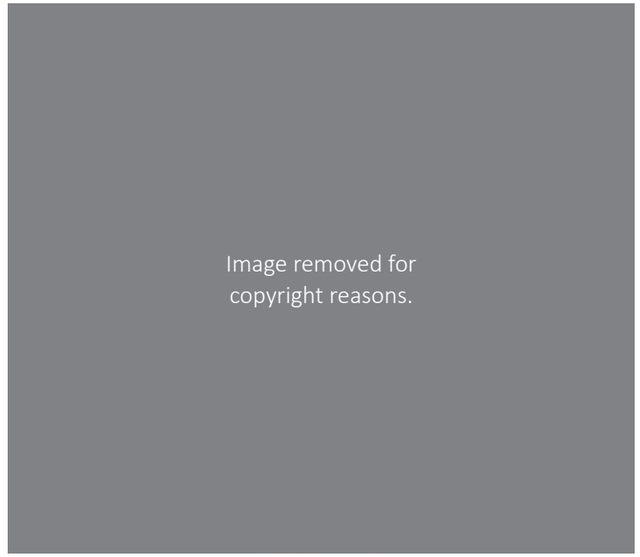


Figure 3. The illustration shows how patients can relive traumatising situations in the dental chair due to the bodily memories triggered by such a vulnerable position. Wolf 2020 p. 4 from "Dental care – an emotional and physical challenge for the sexually abused." Eur J Oral Sci 2020; 128: 317–324

Although dental anxiety is a significant barrier to patients accessing dental care, dental practitioners may not be given adequate training to help manage challenges associated with treating anxious patients. Moreover, difficulties with supporting people experiencing anxiety have a significant impact on dentists' work satisfaction. Goetz (2019) reported that dental practitioners on average claimed 25% of their patients as "challenging" (either aggressive or highly anxious). Furthermore, uncooperative patients extended the length of an appointment, further perpetuating the patient's anxiety and causes delays for other patients. "Challenging" or uncooperative behaviour during dental examinations may result in misdiagnosis due to unfulfilled dental examinations leading to misdiagnoses and more significant dental problems requiring follow-up care, incurring additional costs. An increase in challenging patients also resulted in a higher risk of developing cognitive stress symptoms and risk of burnout for dental practitioners (Goetz, 2019). Burnout results from "chronic interpersonal work-related stressors", and impacts a person's overall well-being (Basson, 2012, p.1). This highlights that dental anxiety not only has a negative effect on patients, but also dental practitioners.

The most common intervention taught in dental training for making patients feel more at ease is establishing a good rapport. Defined as a "harmonious relationship", rapport relates to how patients and physicians create conversation and familiarity. Successful rapport building has proven to improve patient cooperation during procedures, the quality of treatments, and overall patient satisfaction. For example, starting a simple conversation with "could you start with telling me what you do / have done for a living?" Can help to provide a way of gaining insight into a person's life, so they feel appreciated and important (Butt, 2021, p. e663). Impactful communication is described as 7% verbal and 93% non-verbal, where the non-verbal component is composed of body language (55%) and tone of voice (38%) (Butt, 2021). In an age of mask-wearing and physical distancing, maintaining good communication with patients has become significantly more challenging (Butt, 2021). A good rapport with patients can help strengthen long-lasting trusted relationships, meaning a patient may return to the same clinic for ongoing treatments. However, dentists often experience immense time pressures limiting face-to-face interactions with their patients before commencing treatments. An example of the effectiveness of rapport building is captured in the following quote: "When I'd go to the doctor or the dentist, I felt very vulnerable and very often, that's where I'd confide everything that was going wrong. And sometimes, simply the professional smile before me, saying 'Yes, I understand. It's not easy; you are going through tough times' Words that give you hope are much better than pills" (Levesque, 2012, p. 34) This reiterates how constant two-way patient-practitioner feedback during procedures supports patients to "feel involved and consulted in treatment decisions" (Levesque, 2012, p. 34).

Our mind and body are perfectly intertwined. The Autonomic Nervous System (ANS), associated with the Central Nervous System (CNS), modulates the Human Stress Response (Everly & Lating, 2013) (see figure 4). The CNS collects sensory information from the environment, processes the information and initiates a response (Everly & Lating, 2013). The ANS responds by mobilising the body for action (Everly & Lating, 2013). The ANS comprises two complementary divisions, the Sympathetic Nervous System (SNS) and Parasympathetic Nervous System (PnNS) (Everly & Lating, 2013). Once activated, the PnNS responds by calming the nervous system in a "rest and digest" mode (Everly & Lating, 2013). In contrast, once stimulated, the SNS excites a "fight, flight or freeze" response (Everly & Lating, 2013).

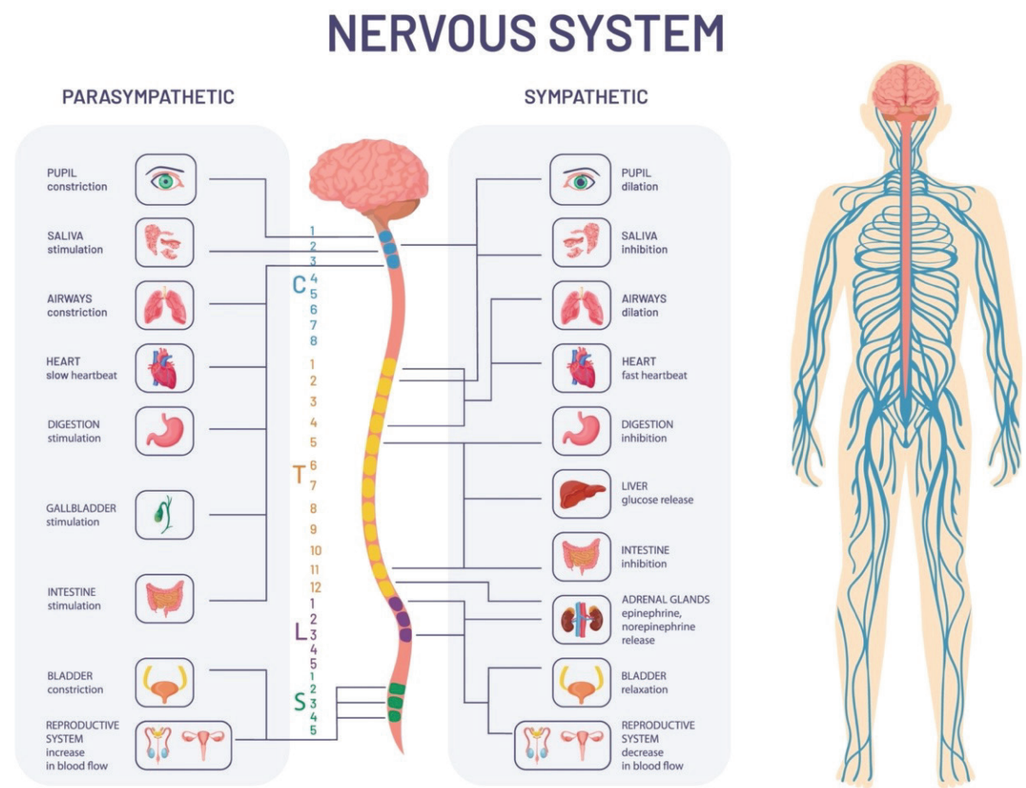


Figure 4. The Parasympathetic and Sympathetic Nervous System and impact bodily functions (Everyly & Lating). Image purchased from stock.

Hence, our sensory appreciation of the world around us directly influences our nervous system and emotional state. The human sensory systems form a continuous feedback loop, connecting brain areas that process reward and decision making and influence behaviour (Dempsey, 2016). The human body comprises receptors that collect information from external senses (e.g., smell, taste, sight, touch) and internal organs ('internal senses') (Dempsey, 2016). Examples of 'internal senses' include proprioception, spatial bodily awareness sensed through skin receptors, muscles and joints; and vestibular senses, which perceive movement, and the body's orientation in space to support balance (Dempsey, 2016; Proske & Gandevia, 2012).

The therapeutic approach, sensory modulation, focuses on the relationship between the environment, senses, and emotional arousal, toward supporting the self-regulation of the nervous system (Brown, 2019). Sensory modulation uses sensory-adapted objects and activities to stimulate the different modes of the ANS (calming PnNS and alerting SNS) and support users in managing emotional arousal (Brown, 2019; Sutton et al., 2013). It is an emerging practice predominately used by occupational therapists and practitioners in mental health or to facilitate individuals with sensory processing disorders such as autism (Blairs, 2007; Brown, 2019).

Sensory stimuli associated with dentistry can activate the SNS ("fight or flight" response") and heighten emotional arousal in patients, thereby increasing dental anxiety. Sensory stimuli such as "loud noises, distinctive odours, bright lights" and "invasive contact in the mouth" (Shapiro, 2007, p. 479).
Examples of sensory-adapted products centred on sensory integration (sensory modulation) theory are, weighted blankets which apply deep pressure touch (DPT), stimulating proprioceptive senses and providing a grounding effect which calms the nervous system (stimulates the PnNS). Furthermore, activities such as gentle rocking sensations (e.g., rocking in a rocking chair or hammock) stimulate vestibular senses also providing relaxation (Dempsey, 2016). Moreover, objects which encourage tactile engagement such as squeezing, stroking, or pulling can be self-soothing and provide distraction from negative thoughts (Sutton, 2013). Additionally, music therapy (stimulation of auditory sensing) has proven to reduce anxiety (Wazzan, 2022). Music tempo has shown to have physiological effects on the body such as breathing and heart activity. Slower musical tempos have proven to slow heart rate and respiration, whereas faster music tempos quicken heart rate and respiration (Agrawal, 2013; Koelsch & Jäncke, 2015). Visually stimulating imagery and light such as light projections offered by 'Snoezelen Multi-sensory Environments' which display soft hues and round slow-moving shapes, also provide calming and visual distraction (Snoezelen Multi-Sensory Environments, 2022) (see figure 5).

Snoezelen environments are multi-sensory installations which encourage interaction with sensory adaptations to engage the sensory system (proprioception, vestibular, visual, auditory, and tactile sensing) (Sigal & Sigal, 2022). These environments offer users freedom to explore and interact in ways most receptive to them and their sensory needs. They are associated with calm and significantly reduce emotional arousal and anxiety (Sutton et al., 2013). Studies have recognised the benefit of sensory-adapted clinical dental environments toward minimising alerting sensory stimuli and reduce dental anxiety in patients (Sharon A. Cermak et al., 2015; S. A. Cermak et al., 2015; Shapiro et al., 2007).

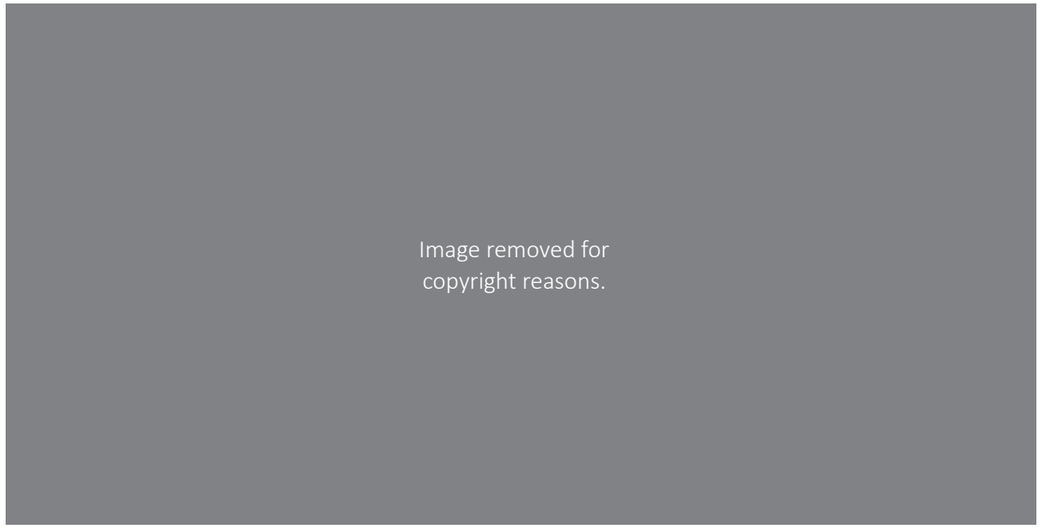


Figure 5. Snoezelen Multi-sensory Environment. Snoezelen Multisensory Environments 2020. Retrieved 16/08/2022. from https://www.snoezelen.info/room-designs/

Some examples of commercially available products which support self-regulation through sensory-based techniques is ‘ImmuRelax’ weighted cushion and ‘Denta Calm’ medical grade weighted blankets (see figures 6. & 7.). ‘Immu relax’ is a company that has developed a weighted cushion, which emits gentle vibrations and soft musical tones to reduce dental anxiety (immutouch, 2020). ‘Dent Calm’ offers a range of weighted blankets varying in size and in material for application of DPT toward reducing anxiety in dental patients (DentaCalm, 2022).

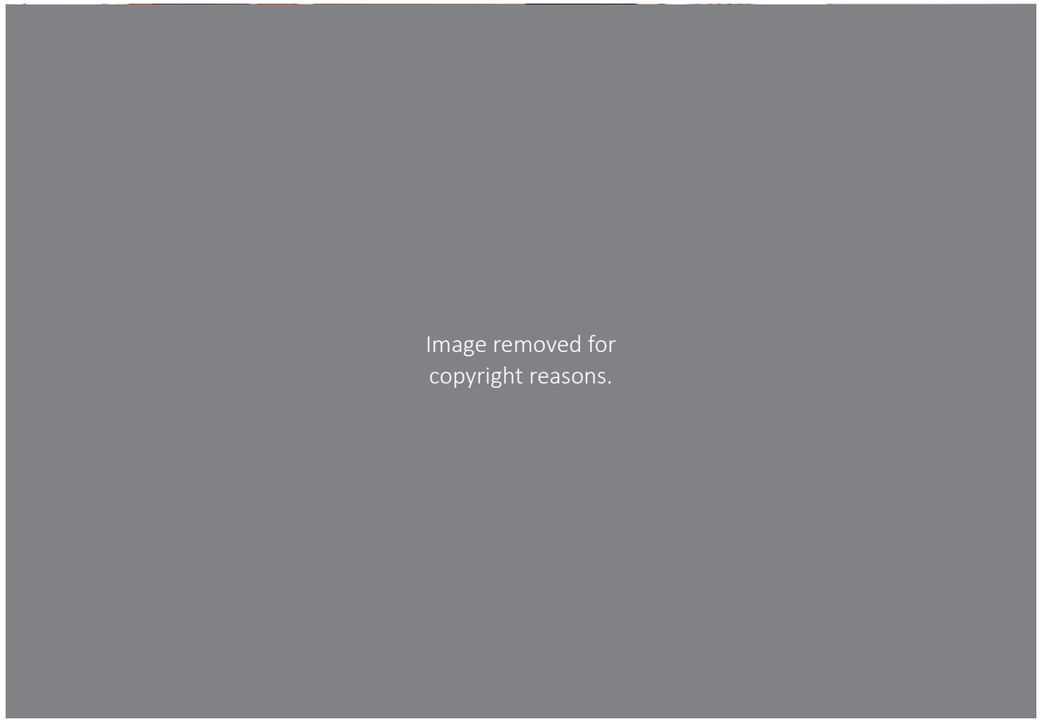


Figure 6. Weighted blanket applying deep pressure touch therapy to calm patient. ‘Denta Calm’ 2022. Retrieved 16/08/2022 from https://dentacalm.com

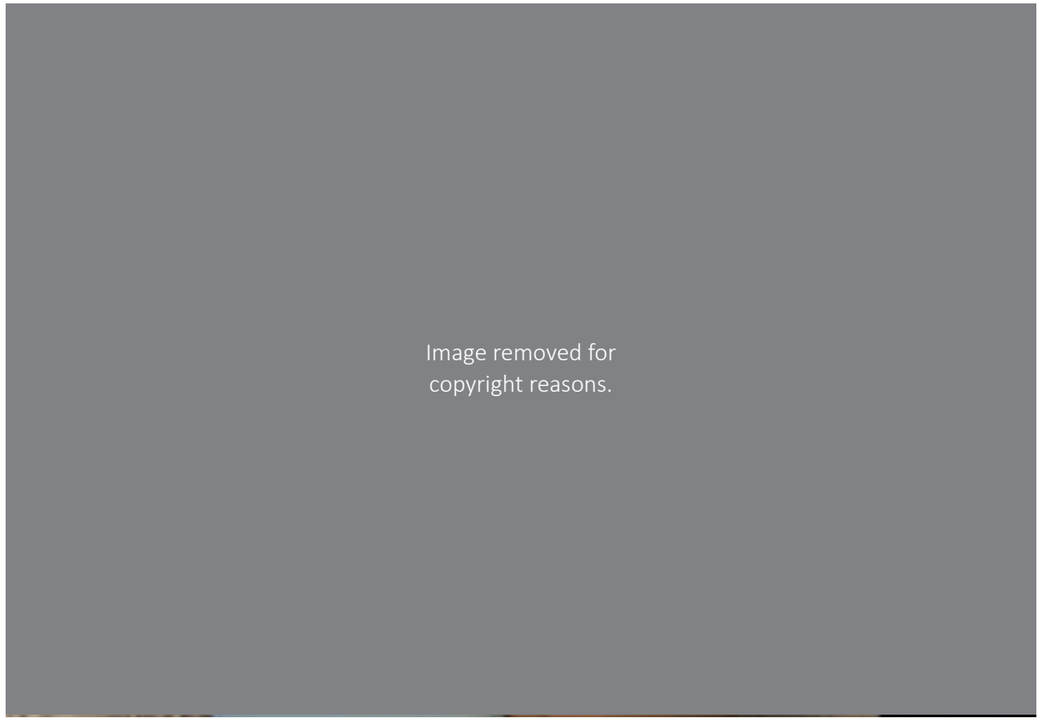


Figure 7. ‘ImmuRelax’ multi-sensory cushion being used in the dental chair. Immutouch 2020. Retrieved 16/08/2022 from https://inmutouch.com

Biofeedback aims to “better probe and discern the biorhythms of the body that might be hard to feel and thereby regulate” (Höök, 2018, p. 77). The purpose of biofeedback is to help users self-regulate physiological functions and autonomic responses, such as heart rate (average heart beats per minute), heart rate variability (variation in time between heart beats, refer to figure 8), as well as other bodily processes like brain activity via electroencephalogram sensors (EEG) or respiration (Hashizume, 2013). These processes are often monitored in real-time. Users can decipher when they are experiencing heightened emotional arousal (activation of the SNS) and employ techniques such as deep breathing to restore the nervous system (Benedict, 2013). Biofeedback has been proven to be effective at reducing anxiety, helping patients manage chronic pain (Schlatter, 2021; Yetwin, 2022).

Heart activity is recognised as a strong indicator of physiological and psychological arousal (Brás, 2018). High HRV demonstrates that your body can adapt rapidly to various stressors and shows how effectively your body regulates the nervous system (An, 2020). HRV provides a reliable way of discerning an individual’s thought patterns, emotional reactions and behaviour as a biomarker of the autonomic nervous system (Hashizume, 2013) .

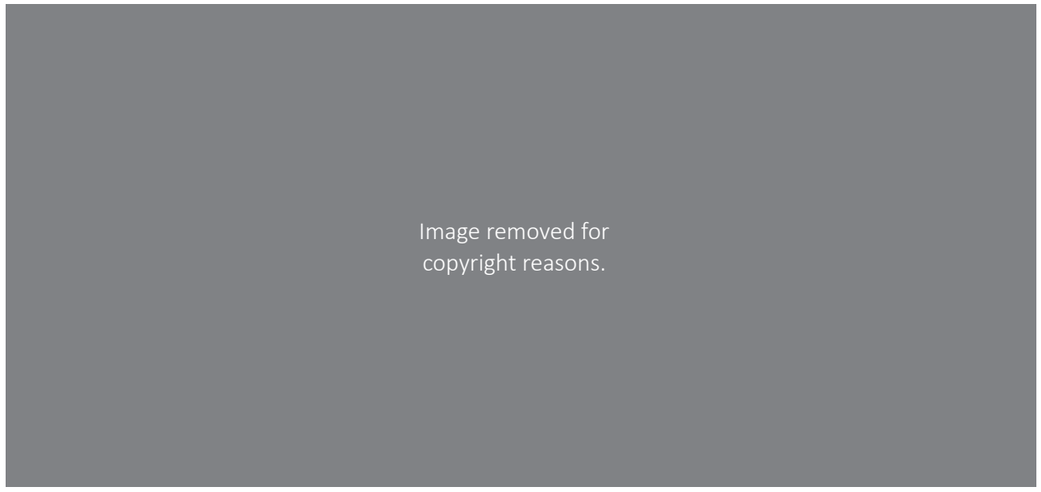


Figure 8. Diagram explaining heart rate variability and how it is measured. Kits Energy 2022. “Use HRV To Optimize Training And Recovery.” Retrieved 22/06/2022, from https://kitsenergy.com/?s=heart+rate+variability.

There are a various ways of measuring HRV data, a common method is using Photoplethysmogram (PPG) sensors (often integrated in smartwatches), which use light-based technology to read rate of blood flow through the skin surface (Galli, 2022). However, Electrocardiogram (ECG) sensors which monitor the electrical pulses emitted by the heart provide millisecond time precisions, making it a more reliable way for analysing and pinpointing the timing of emotional and physiological processes (Brás, 2018; Galli, 2022). ECG monitoring requires electrodes (comprised of highly electrically resistant metals) positioned directly onto the skin surface where electrical signals are reflected from the heart (Carroll, 2013). At least two electrodes need to contact skin on either side of the heart. For instance, on the chest or on both the right and left hand (Carroll, 2013). Two different types of electrodes are used for ECG monitoring, dry and wet electrodes. Dry electrodes are convenient alternatives to wet electrodes because they do not require any gels as a medium to transfer electrical signals from the skin. Dry electrodes are also more practical long term because they are usually low cost, stretchable, portable, and small in size (Galli, 2022, p. 5). Five minutes of continuous skin contact with ECG electrodes is considered an appropriate duration to gather comprehensible HRV data (Nussinovitch, 2011).

Another type of biosensing complementary to ECG for assessing an individual’s mental state is the bodies electrodermal response. Electrodermal activity sensors measure the electrical conductivity of an individual’s skin. When an individual experiences heightened emotional arousal fearful emotional state, skin conductance increases (Critchley & Nagai, 2013; Jacobs, 1994).

Data collected from biological sensors can give feedback in different ways, which can then be used to engage other senses. HRV data can translate through audio, vibrations and light (Hashizume, 2013). The system and product ‘Breathe with Touch’ translates bodily data into tactile feedback by imitating the contraction and expansion of the lungs—an example of how biofeedback can positively influence a person’s breathing to support calm (Bin Yu, 2017). In this system, A PPG sensor placed under the user’s forefinger measures HRV data. In addition, a respiratory sensor applied to the user’s abdomen assesses

The device, ‘RESPeRATE™’, also provides guided breathing by translating respiratory data into musical tones to suggest a restful breathing rate (see figure 9). Respiratory data is gauged through a respiratory sensor (RIP), a belt placed around the user’s abdomen to detect abdominal contractions and expansions as an indicator of breathing. The investigatory trial for ‘RESPeRATE™’ aimed to alleviate dental patients' "pre-operative general anxiety levels", consequently relieving pain associated with dental injections and providing an “overall pleasant experience.”(Morarend, 2011, p. 64). Contrasting rhythms and tone variations act as cues indicating inspiration and expiration. The expiration tone plays slightly longer than registered breathing to encourage deep breathing to slow heart rate and calm the nervous system (Morarend, 2011).

Figure 9. ‘RESPeRATE™’ device. RESPeRATE Inc. 2021. Retrieved 16/08/2022 from https://www.resperate.com/how-it-works/

The ‘Vibreathe’ system targeting work-related stress integrates PPG sensors for recording HRV, pressure sensors for tactile interaction and a vibration actuator for generating vibrations for breathing guidance (see figure 10). These vibrations change intensities to cue inspiration and expiration while responding to the user’s stress levels. A small LED light provides visual guidance (Yu, 2021).

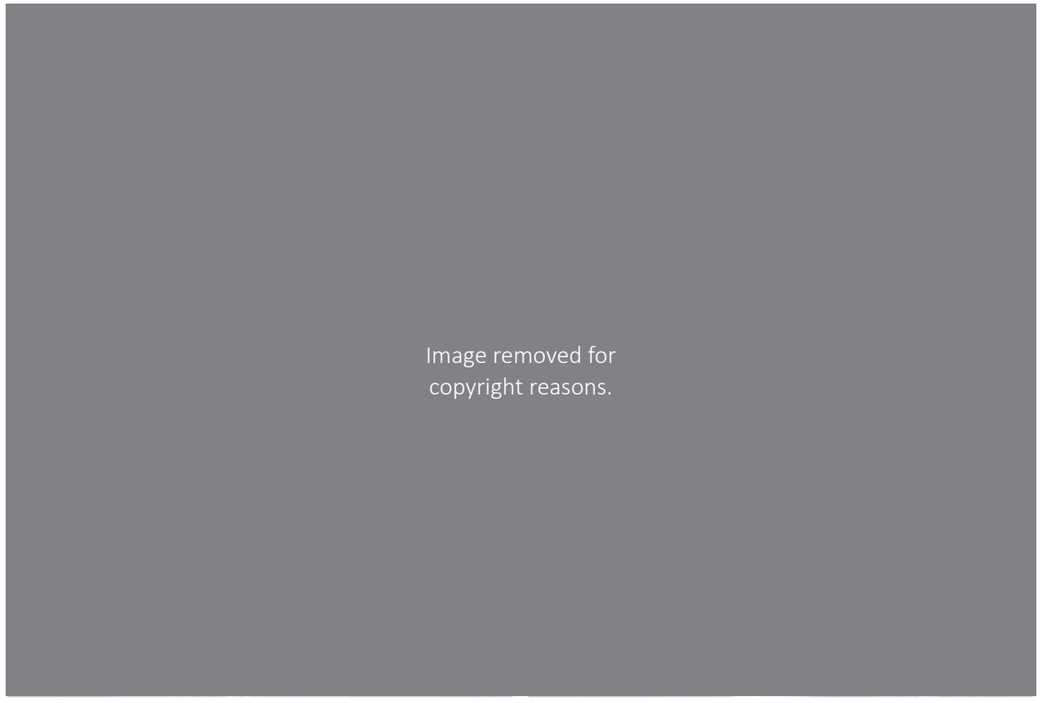


Figure 10. Vibreathe, a soft tactile biofeedback interface for reducing work stress. Yu 2021. “ViBreathe: Heart Rate Variability Enhanced Respiration Training for Workaday Stress Management via an Eyes-Free Tangible Interface” from International Journal of Human–Computer Interaction.

‘DeLight’ is a lighting system which reacts to the user's HRV data by changing the intensity and hue of the ambient environment to provide relaxation and biofeedback (see figure 11). The ‘Delight’ system comprises a PPG sensor and multiple lighting fixtures which respond to HRV data (Yu, 2018). When the user’s HRV decreases, suggesting a high level of stress, the lighting fixtures respond by warming in hue. In contrast, when HRV increases, it changes to a cool shade (Yu, 2018).

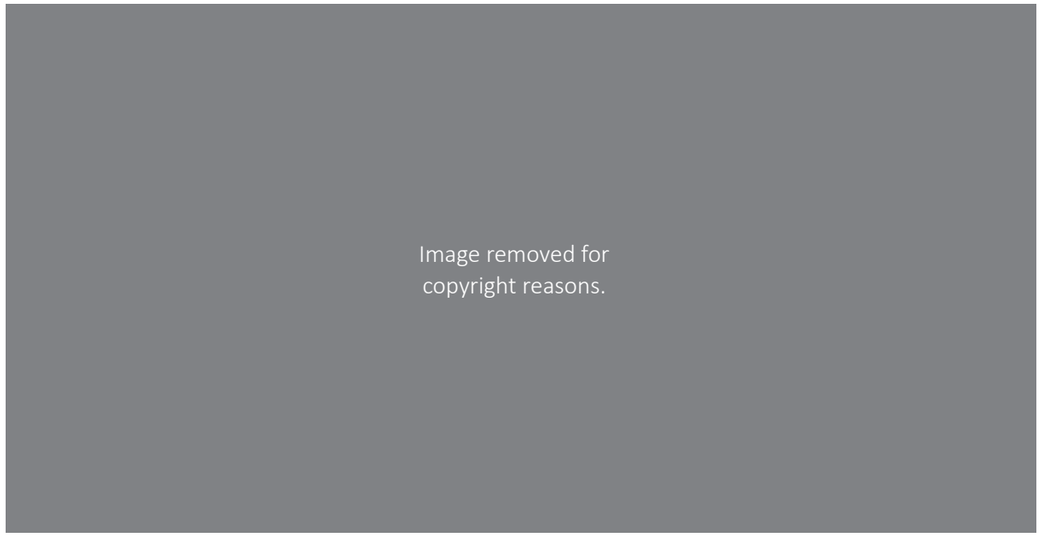


Figure 11. DeLight lighting system. Yu 2018.“DeLight: biofeedback through ambient light for stress intervention and relaxation assistance.” Personal and Ubiquitous Computing 22(4): 787-805.

To conclude, dental anxiety is a significant barrier for patients accessing dental care, which powers a relentless cycle of avoidance behaviour, dental problems, and symptom-drive care exacerbating fears. Patients’ reasons for developing dental care can vary, including previous negative experiences, trauma, existing mental health conditions, and anxiety or pain. The sensory environment of dental clinics has been identified as a cause that heightens patient arousal due to the connection between our senses and the autonomic nervous system responsible for regulating emotional arousal. This contextual review uncovered an opportunity to explore further how the dental care environment could be adapted to minimise potentially distressing dental-related stimuli for patients; moreover, provide better-coping methods for anxious patients using sensory modulation techniques for relaxation and moderation of the automimic nervous system toward regulating emotional arousal. Furthermore, this contextual review explored the potential application of biosensing technology for measuring anxiety levels in patients combined with relaxation techniques to reduce anxiety.

Research Question:

How might we help alleviate dental anxiety in patients through the design of sensory modulation techniques and biofeedback systems for calming?

Aims:

This study aims to combine the elements explored to develop a product that facilitates dental practitioners and helps patients manage dental anxiety, subsequently stopping the cycle of avoidance and dental problems associated with dental anxiety and improving health outcomes for patients.

The key aims of this research were to:

- To better understand different peoples' perspectives on dental care and identify new design opportunities to improve patient experiences
- Explore how sensory-based systems and objects may be used to help alleviate dental anxiety.
- Explore ways sensor technology and biofeedback might be used to assess and help patients manage their dental anxiety.

Methodology

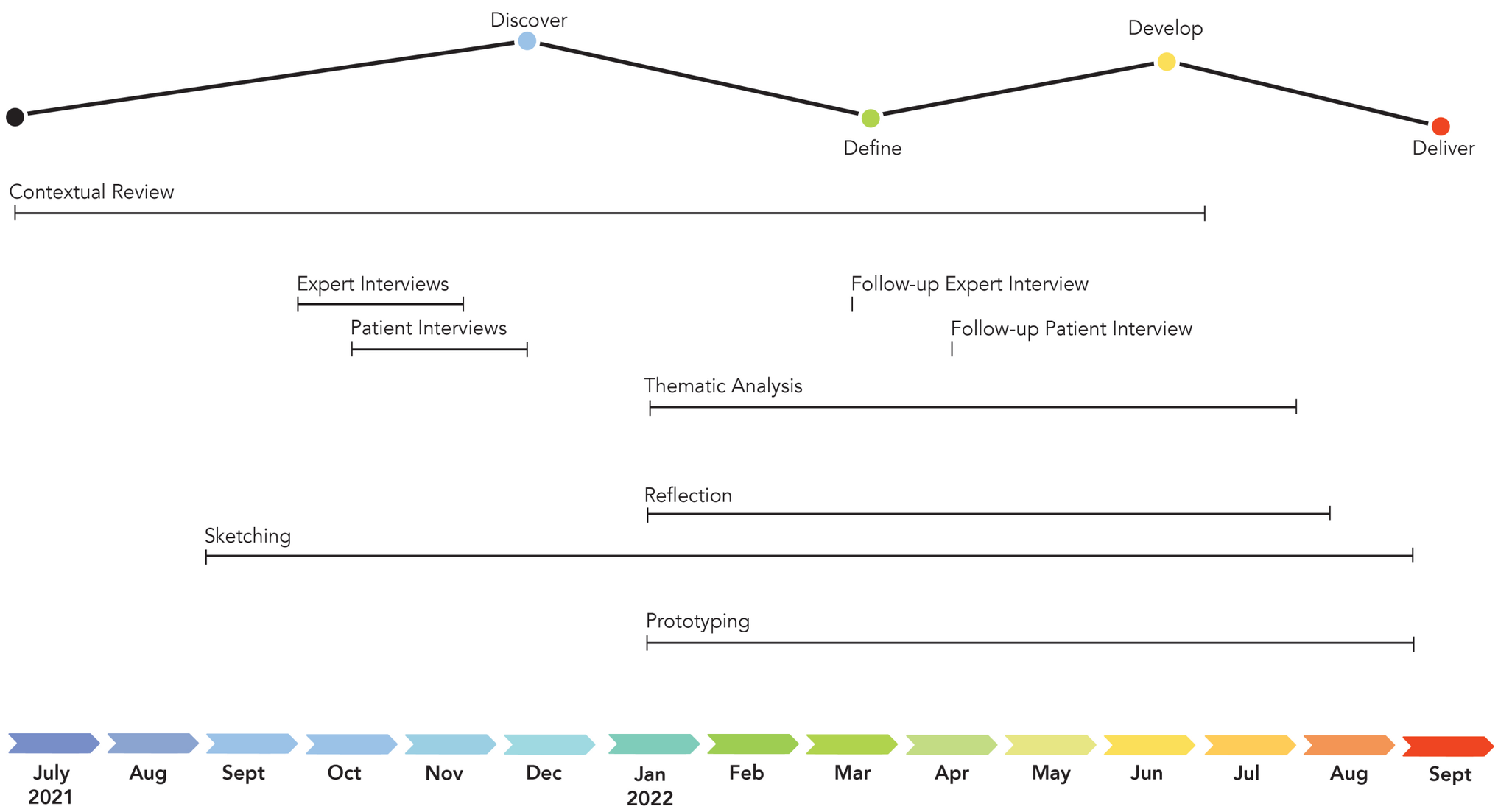


Figure 12. Methods timeline.

Action Research

The methodological approach, action research (AR), brings together action and reflection, theory and practice, in participation with others, towards delivering better outcomes for communities (Brydon-Miller, 2003). Action research fosters an iterative cycle of discovery and analysis, an approach recognised as an effective way of examining and solving problems related to health care services (Koshy, 2011).

Action research combines four modes, 'planning', 'acting', 'observing' and 'reflecting' (see figure. 13) (Burns, 2015, p. 189). Meaning to identify a problem or pose a question ('plan'), demonstrate a solution ('act'), 'observe' and determine successes and failures ('reflect') of outcomes. Each new learning derived from these modes feeds into a new cycle (replanning) (Burns, 2015).

When used as a participatory approach, action research supports qualitative research methods for gathering data, such as participant interviews, which provide the 'why' and reasoning behind a solution (Busetto, 2020). Applying AR methodology in my research led me to produce both research and design outcomes. For example, I applied qualitative methods of discovery by engaging with dental patients and experts in dentistry, psychology, and the design of patient experiences in healthcare (Koshy, 2011). These interviews helped identify problems and 'plan' experiments as a response to insights. For instance, sketching and prototyping ideas, 'observing' how they functioned, and determining what value they added to my project. Then, transferring my learnings into the next phase of 'plan' 'act ', observe 'reflect' to reach new insights. The exploratory AR approach helped me follow my hunches and embrace failures as steppingstones to better solutions toward solving my research problem (Muratovski, 2022).

Figure 13. Iterative cycle of AR. Adapted from Koshy 2011. "What is Action Research Action Research in Healthcare" from Sage Publications Ltd.

Human-centred Design

A human-centred design (HCD) approach centres design outcomes on users' needs by empathising with users' perspectives and experiences (Steen, 2011). Applying HCD principles in design ensures designers are held accountable for the ethical consequences of design outcomes (Krippendorff, 2004). Building empathy with users was crucial in my project to identify how anxiety affected patients, where anxiety manifested in their bodies and what methods would be most beneficial for them. Everyone experiences anxiety and pain differently, so it was essential I challenged my own assumptions and beliefs about anxiety and focus on what users truly wanted and would benefit from the most. My interaction with patients and dental experts helped me prioritise their needs and base my decision-making on the insights I gathered from interacting with participants.

The UK design council is universally renowned for its double diamond method. I followed this structure in my research. To 'discover' problems and gather insights, 'define' a direction or focus for the project, 'develop' my chosen idea and 'demonstrate' the outcome (Ball, 2019). I structured my research in divergent and convergent stages (refer to figure 12, pages 30-31).

The discovery phase of my research involved exploring initial ideas and hunches and conducting interviews with experts and dental patients. My insights from participant interviews helped define the focus of my project, leading me into the next stage of my research journey of developing a final design outcome. I used methods such as existing product analysis, sketching primarily, brainstorming, and reflection during this stage. I outlined a design brief to define my objectives for the project and follow-up interviews with potential users to validate my chosen direction. Finally, developing and demonstrating my developed outcome through sketching, prototyping, testing ideas and executing an outcome.

Contextual Review

A contextual review helps researchers summarise, analyse, and synthesise past works as the basis for further investigation (Crouch & Pearce, 2012). To identify gaps in knowledge, pose a research question, and provide a rationale for the project's direction (Crouch & Pearce, 2012).

I constructed a contextual review early in my research project to provide a contextual background on dental anxiety, for example, the prevalence of dental anxiety in patients and underlying dental fears. In addition, potential ways to reduce patient anxiety such as sensory modulation and biofeedback technology, and identified existing systems and products aimed at reducing dental anxiety or stress. The analysis of these contexts helped define opportunities for further research.

The literature I identified in this contextual review was sourced from AUT library data bases, on-site at AUT City Library and online via google. I used keywords or phrases such as sensory modulation, sensory-adapted, biofeedback, stress, interaction, Snoezelen, nervous system, and emotional arousal. Relevant texts were saved and stored via Endnote referencing system and organised into categories using formatted tables in Word to construct contexts before writing up.

Expert Interviews

An expert is a specialist in their field of research or practice (Döringer, 2021). Expert interviews are qualitative research methods for gathering background knowledge and a system-level perspective about topics of investigation (Döringer, 2021).

Participants

I interviewed experts in dentistry, such as dental therapists and hygienists, and a dentist (educator and academically researched in dental anxiety and dental anxiety questionnaires). I also interviewed experts in psychology and academics interested in the philosophical ideas and applications of mindfulness and experts in improving patient experiences in healthcare and engaging with patient participants in research. The duration of these interviews was between 30-45 minutes. A total of six interviews, three of which were dental experts.

Recruitment

Experts were identified from information accessible in the public domain and supervisors' and advisors' professional networks. Participants were invited by email, providing a short description of my area of focus for my research and potential interview questions. Email invitations also provided an attached participant information sheet and consent form (see appendix D). The potential participants were given two weeks before a follow-up email was sent as a reminder. After this period, no contact was made.

Interview Structure

I took a constructivist approach to expert interviews. A constructivist approach means interviews were co-constructed by myself (the interviewer) and the interviewee and went beyond extracting background knowledge to empathise with the expert's unique perspective (Roulston, 2010). For example, I encouraged participants to describe, explain, and justify issues they encountered in dentistry or methods to manage these issues, such as identifying anxious patients and treating anxiety in the dental chair or waiting room (Roulston, 2010).

I asked participants five semi-structured questions about how often they treat anxious patients.

Indicative Questions:

- How often do you experience anxious patients?
- What do they do/how do they show their anxiety?
- How do you know they are anxious?
- How do anxious patients interrupt how you perform procedures?
- Have you tried or have experience using sensory (or other) methods to help them manage their anxiety? If so, what works well?
- From your experience, what other methods or approaches for reducing dental anxiety would be most appropriate for me to explore?

I conducted one follow-up interview with an expert dentist, who had consented to be contacted for a follow-up interview. I presented images of designed concepts in this interview and demonstrated physical prototypes.

User Interviews (Patient Participants)

User interviews help bring to the surface the “opinions, attitudes and perceptions” of potential users and inform human-centred design decisions (Martin, 2012, p. 102). This research involved the participation of individuals who perceived themselves as dentally anxious. The involvement of patient participants helped me gain vital insight into how design can serve those who experience dental anxiety and improve dental care experiences for all.

Participants:
All individuals who participated in this research were aged 18 and over, spoke English, shared lived experiences of accessing dental services, and experienced anxiety when accessing these services.

Recruitment:
Participants were recruited through a healthcare institution which provides a range of healthcare services, including oral healthcare (refer to appendix G for the participant information sheet). The oral health department primarily provides services for scaling, cleaning, fillings, and dentures.
Upon registering at the healthcare institution, participants who had consented to be contacted for research purposes and had visited the oral health department within the last two months were invited to participate, resulting in four participants (see table 2 below). Approximately three months later, a second email invitation was issued, inviting potential participants across all departments of the healthcare institution who had consented to be contacted for research purposes, resulting in additional two participants. In total, 1500 potential patient participants were contacted via email invitation.

Table 2. Patient Participant recruitment respondents and participants.

Patients **Total Invited:** Approx. 1500 clients	**Recruitment 1** October 2022 Clients who had accessed dental care services in the last two months.	**Recruitment 2** February 2022 Clients who had visited the health care institution within the past year.	**Follow-up** April 2022 1 participant invited
Respondents: (Expressed Interest)	8	6	1
Participants: (Consented & participated in research)	4	2	1

Total Participants: 6

Location:
Due to the 2021 covid-19 restrictions from August through to December, these interviews were conducted online via video or phone call. One follow-up interview with participant ‘Emma’ was conducted in person on-site at the healthcare institution I recruited participants from.
I started the interviews by introducing myself and my project and building a good rapport with my participants. In three of the first interviews I conducted, I presented my research topic by playing a 2-minute introductory video with dialogue and audio, which communicated the importance of my study and gave examples of sensory modulation techniques. The participants then shared their personal stories of previous dental care experiences.

I used a visual prompt from the six participants I interviewed to structure the interview process and pinpoint areas of the patient journey of dental services resulting in the onset of negative thoughts or uncomfortable bodily sensations. I used the online brainstorming platform, 'Miro' to share the visual prompt with participants via Zoom video ‘screen share’ (Miro, 2022). To not overburden participants, I transcribed participants' responses directly onto maps without their assistance.

Indicative questions:

- When do you start to feel anxious, and what causes you to feel the most anxious? For example, when you book an appointment, wait in the waiting room, or receive treatment?
- How does anxiety manifest in your body?
- For example, do your hands and legs shake, become tense, sweaty, or uncomfortable.
- Have you noticed certain noises or sensations trigger your anxiety? For example, the sound of the drill, unpleasant smells, or sights. Can you describe these sensations and how they made you feel?
- Do you practice or use any techniques for calming yourself in stressful situations? For example, meditation, weighted blankets, breathing exercises or others.
- Have you ever shared your feelings of anxiety with your dentist?
- I conducted one follow-up interview with patient participant Emma, who had consented to be contacted for a follow-up interview. The aim of the interview was to gain feedback about the direction of my project. I demonstrated physical prototypes to communicate my designed concepts.

Interviews were audio recorded and transcribed for analysis. Participants have been kept anonymous in all data documentation, except for myself and my supervisors. To improve the flow of writing participants, I used pseudonyms to describe participants so they could not be identified. Participants could opt out of participating in this research before data analysis without being coerced or disadvantaged.

Cultural Probes

Cultural Probes are physical and visual "tools for understanding" and 'probe' more profound thought toward a specific theme or question (Jayne Wallace, 2013, p. 1). Probes offer a creative way of supporting participants or stakeholders in research to understand ideas and promote meaningful and engaging discussions between researchers, other collaborators, stakeholders, or participants (Connor Graham, 2008; Jayne Wallace, 2013). They prompt participants to share lived experiences and thoughts in a comfortable and approachable way (Connor Graham, 2008; Jayne Wallace, 2013).

I used this method in my interviews with patients or 'user' interviews to structure my interviews with patients and prompt patients to reflect on each stage of their experiences accessing dental care, from booking appointments and receiving treatment to paying at reception (see figure 14). The design of the visual probe combined methods such as user journey, as well as emotion and bodily sensation mapping (Martin, 2012; Nummenmaa et al., 2018; Yodan Rofé, 2013).

The map or system displayed the different phases of a typical dental care service:

1. Booking an appointment.
2. Travelling to the appointment.
3. Reception.
4. 'Meet and greet', an initial encounter with a dental practitioner.
5. Receiving treatment.
6. Paying at the reception.
7. Travelling Home.

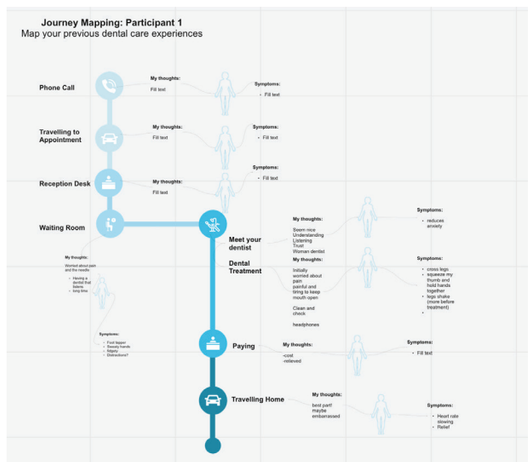


Figure 14. Example of cultural probe used in participant interviews on the online platform Miro (see appendix H).

Roleplaying

Roleplaying refers to “acting the role of the user in realistic scenarios can forge a deep sense of empathy and highlight challenges, presenting opportunities that can be met by design.” (Martin, 2012, p. 132). Using roleplaying in my research helped me relate to patients and empathise with some of the discomforts of sitting in the dental chair. I personally visited the healthcare institution where I recruited patient participants and lay in one of the dental chairs. I wore a lead blanket, used for preventing radiation exposure (see figure 47 on page 92). I also used roleplaying to test my prototypes, by sitting in a reclining chair like that of a dental chair with soundscapes of dental related noises playing in the background to simulate a dental care environment.

Design Methods to Define and Develop

Sketching

Sketching is used to generate, develop and communicate designed concepts (Parsons, 2009). I used sketching as a tool for reflecting and expressing and giving form to my thoughts and ideas. I used this method continuously throughout this project from the conceptual discovery phase of my research to the developing phase of my research where I used sketching to create iterations of my designs.

I used this method to quickly illustrate ideas and communicate them to others for feedback. Occasionally, I would set a timer and challenge myself to develop a series of concepts in a specific time frame. For instance, drawing one concept every ten seconds for 1 minute. This way, when I lacked inspiration, I could generate ideas fast and without overthinking to discover new ideas.

Brainstorming

Brainstorming helps to distil information and provide a visual overview of an idea or problem. The encourage quantity over quality creating space to reflect and explore ideas freely, without the pressure of a well define and thought through outcome (Gray, 2004). Brainstorms not only help to document and map out ideas, but to structure, order and simplify complex information in the form of sketches, images or words, hence, making ideas and themes easier to track and refer to later (Martin, 2012).

I used brainstorming as a way of reflection, for example, to reflect on data I collected from my participants and to explore possible solutions and ideas. In addition, I used brainstorming to structure user experiences concerning the different stages of a patient’s journey through dental care environments, for example, from booking appointments through to receiving treatment.

Design Brief

A design brief is a set of criteria used to communicate critical information and objectives for achieving a successful solution (Sadowska & Laffy, 2017). Design briefs help evaluate designed concepts to ensure they align with the project's focus and ensure a more efficient design process by quick elimination of irrelevant ideas outside the criteria of the brief (Sadowska & Laffy, 2017). Design briefs can be adapted by designers throughout the project as new insights arise, or as the project direction becomes more refined (Sadowska & Laffy, 2017).

After analysing most of my data from interviews and gathering research from literature and existing product analysis, I constructed a design brief. The design brief was revised and adjusted to ensure the deliverables were achievable in a master's project timeframe. New insights shifted the design brief during the defining stage of my research. However, constructing a brief early was essential for keeping the project on track and focused on critical objectives.

Existing Product Analysis

Existing product analysis defines a product's purpose, benefits, and limitations, and identifies design features such as a product's materiality, technological attributes, and user interface for comparison (Hammond, 2021).

I used this method throughout my research phase of my research. I used Google search engine and keywords such as biofeedback, interaction, dental anxiety, sensory-based, haptics, somaesthetic, weighted, HRV, anxiety. I examined existing products that related to my project to support my project direction and to pinpoint features I could explore further in my design or combine in a concept.

Prototyping

Prototyping is a way of visualising concepts, problem-solving, testing and demonstrating ideas (Martin, 2012). Designers typically use prototyping to test functions, explore form language, present and demonstrate designed concepts to others (Martin, 2012).

I used prototyping to give form to my ideas, test the scale and shape of objects in relation to the body, explore materiality and demonstrate how a user might interact with the designed concept. I explored materials such as latex, silicones, fabric and knitted textiles to realise a design outcome. To develop and construct the final design outcome of this project I used 3D-knitting software 'Shima Seiki APEX 4' to program electrical circuits, apply knit structures and colours to achieve a knitted e-textile (Shima Seiki, 2022). I used 'Solidworks' Computer Aided Design software to construct the desired form of to house electrical components (refer to page 159, figure 111) (SolidWorks Corporation, 2022).

Mood Boards

Mood boards are used widely across design disciplines as visual tools for conceptualising products and communicating the desired 'feel' or aesthetic of a product. In addition, illustrate and visually describe characteristics specific to users and user trends. Mood boards can consist of various collaged images of textiles, and textures, features and functional elements (White, 2016).

I used mood boards in the develop phase of my project to communicate my desired look and feel of my project as a basis for further exploration through prototyping and sketching.

Thematic Analysis

Thematic analysis (TA) is a research technique used to analyse qualitative data such as interviews or questionnaires (Clarke & Braun, 2017). TA provides a systematic way for researchers to gather insights on their participants' lived experiences, views and perspectives, behaviours, and actions (Clarke & Braun, 2017). This method of organising qualitative data helps identify, analyse, and interpret 'patterns of meaning' (codes and themes) within a dataset (Clarke & Braun, 2017). Braun and Clarke orchestrated a 'six-phase' guide for conducting a thorough thematic analysis.

- Step 1: Become familiar with the data (e.g., re-reading transcripts and notes)
- Step 2: Generate initial codes
- Step 3: Search for themes
- Step 4: Review themes
- Step 5: Define themes
- Step 6: Write-up
  (Maguire & Delahunt, 2017, p. 3354)

Once the research has been sorted and coded, the researcher can start to identify and name overarching themes suggested in the data, review these themes again, solidify them and explain them in a written sequence to the reader (Maguire & Delahunt, 2017).

To become "familiar with the data", I read and re-read transcripts and notes taken during my interaction with participants. I anonymised transcripts and made physical copies of raw data. To synthesise initial codes and search for themes I highlighted, sketched and took notes of insights I gathered using colour to differentiate between themes (see figure 15). I then began documenting my insights and review my themes, provide supporting evidence in literature to support these themes, before solidifying them in my writing. TA helped me to better understand the data I had collected and ensure what information I recorded was meaningful, used to guide my decision-making and clarify my aims for my project.

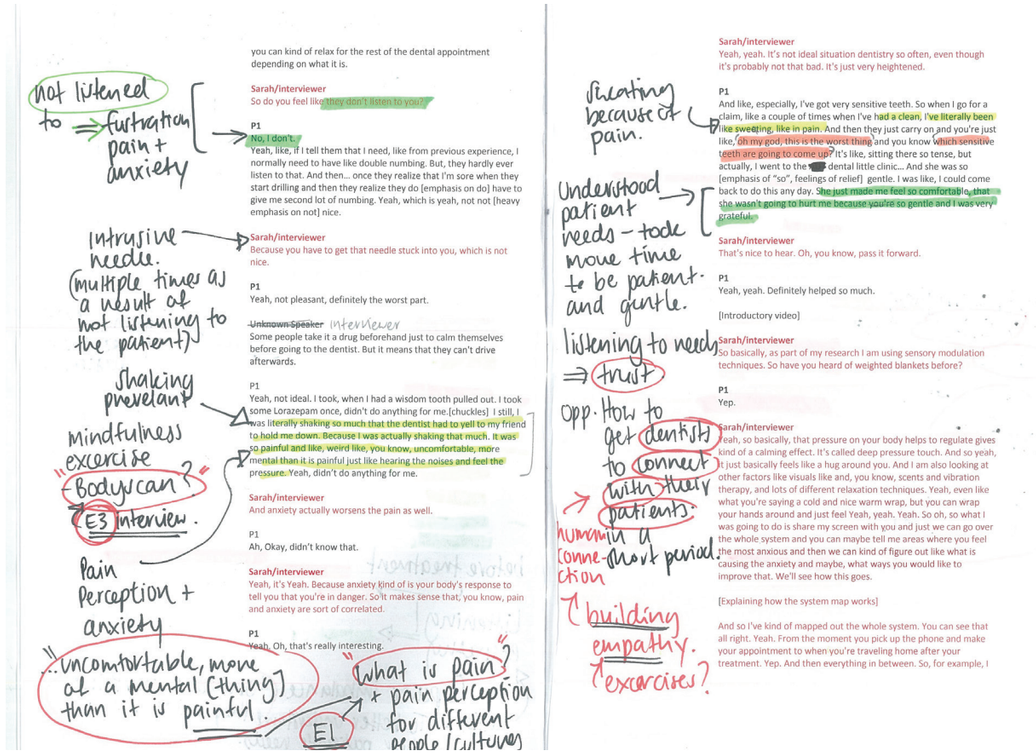


Figure 15.Thematic analysis booklet.

Reflective Practice

Reflection is a crucial part of action research. I reflected on phases of my research journey, mapping out my assumptions and gaps in knowledge and created brainstorms or notes to document key insights I had gathered to define the next phase of idea generation (Currano & Steinert, 2012). Using reflective practice also ensured I kept focused on my aims for the project and what problems I discovered from interacting with participants, making sure my ideas aligned with the needs of my potential users. Talking with others and sharing some of my insights also helped spark ideas and excited me more about my project. I would sometimes would go for a walk or take a different route to the university to change my scenery. Often this would help clear my head, and I would arrive back filled with ideas. It also challenged me to view my research from a different perspective (Currano & Steinert, 2012).

Ethical Considerations

Interacting with participants meant carefully considering how I recruited and conducted my interviews with participant and assessed potential risks related to interacting with participants. For example, minimising any potential discomfort participants may experience when sharing their lived experiences with me.

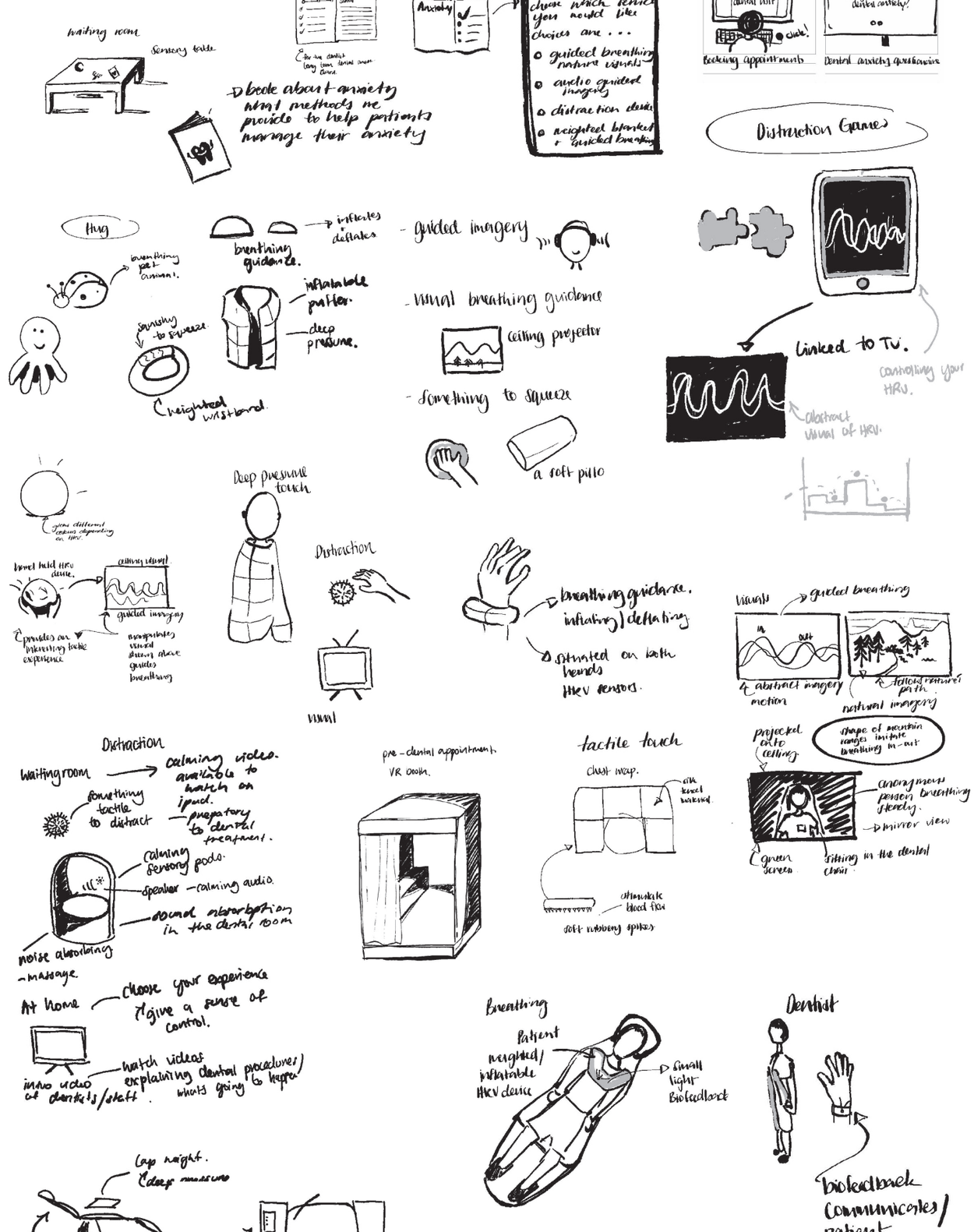
The involvement of research participants in my research was approved by AUT's Ethics Committee on 7/09/2021.

AUTEC Reference number: 21/285

Refer to participant information sheets in appendices.

Discover Chapter

In this chapter, I uncover a range of potential interventions for reducing dental anxiety using brainstorming, sketching, and thematic analysis. I examined the patient experience as a whole, from booking appointments, waiting room environments, dental procedures, and lastly, paying at reception and returning home. This comprehensive outlook helped me identify and provide reasoning for interventions suited to different moments in a patient's journey. Furthermore, it helped me realise key areas I could improve through design.



Mapping Calming Sensations

I used brainstorming and quick sketches as a way of reflecting on my own experiences and findings from my contextual review of knowledge. I started by naming sensations I associated with calm and relaxation. I categorised words and phrases (refer to figure 16) according to what senses they stimulate, such as hearing, sight, and touch.

Sounds I considered calming were sounds of birds chirping, the rustling of leaves on trees, a soft-spoken voice, guided imagery, and storytelling. I recognised the potential for calming audio to disguise unwanted dental-related stimuli such dental drilling or worried voices from other patients, which are sounds I identified in my contextual review as heightened anxiety in patients.

Examples of 'calming sensations' I described relating to sight were round shapes, slow-moving shapes, and warm hues. Comforting textures which engage tactile senses included animal fur or silk, which reminded me of pleasant experiences such as petting a pet animal or receiving a warm embrace from a loved one- sensations which evoke feelings of security and tranquillity.

This exercise sparked my creativity, which lead me to explore more ideas.

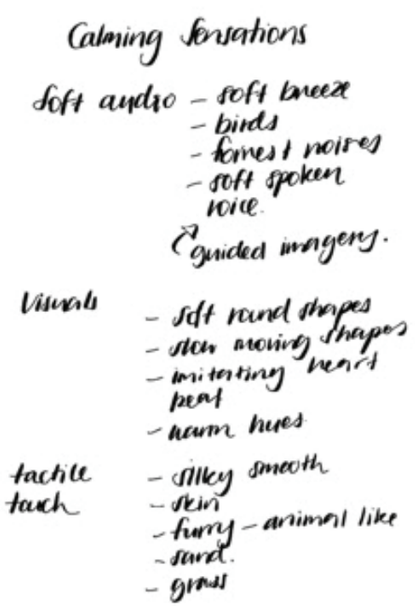


Figure 16."Calming Sensations". A word map for naming and characterising 'calming' sensations.

Mapping Calming Sensations

At this stage of discovery in my design process, I explored various ways of improving experiences for dental patients, which extended to offering patients a warm cup of tea or a sensory room devoted to calming anxiety. As mentioned in the contextual review, dental anxiety powers a cycle of dental anxiety, avoidance, and dental problems. Anxious people often cancel or delay appointments, prompting me to consider how patients book appointments. Whether patients phone the reception to request an appointment or book online, this led to a consideration of all the different steps involved in a dental appointment. Thus, following the booking of the appointment, patients need to check in at the reception and wait in the waiting area (a place associated with anticipation and frustration) and receive treatment. Since all these different moments contribute to patients' anxiety in some way, I decided to brainstorm interventions for each of these steps (see figure 17 on page 52).

Examples of ideas for online booking of appointments I included consultations with dental practitioners, whether online, via video chat, phone call or on-site, to devise a unique treatment plan to minimise specific dental-related stimuli or address patient concerns regarding treatment. Another option is a short dental anxiety questionnaire accessible online that patients can fill in pre-appointment and send to their dentist or hygienist. Other ideas to help prevent patients from avoiding appointments comprised filming short introductory videos from practising dental practitioners available online, to reassure patients of the dental practitioner's dedication to caring for the patient's well-being.

Furthermore, 360-degree virtual tours of the dental clinic could be useful as these would allow patients to virtually explore the clinic before their appointment. I discovered that some dental clinics have already added this feature to their websites. 'Sanctuary Dental', a dental clinic located in Auckland, New Zealand, shows the entryway for accessing the building, the waiting room interior, reception desk, and consultation room (Sanctuary Dental, 2022). This is an example of an easily implementable solution toward eliminating some of the worry hindering patients from attending appointments (Circus360, 2019).

Ideas for the waiting room included having therapy dogs or cats available for patients or offering them quiet private areas with comfortable furniture where they can relax. Simple solutions including offering puzzles to distract patients or options for them to listen to guided imagery or mindfulness exercises on an iPad or tablet provided by the clinic.

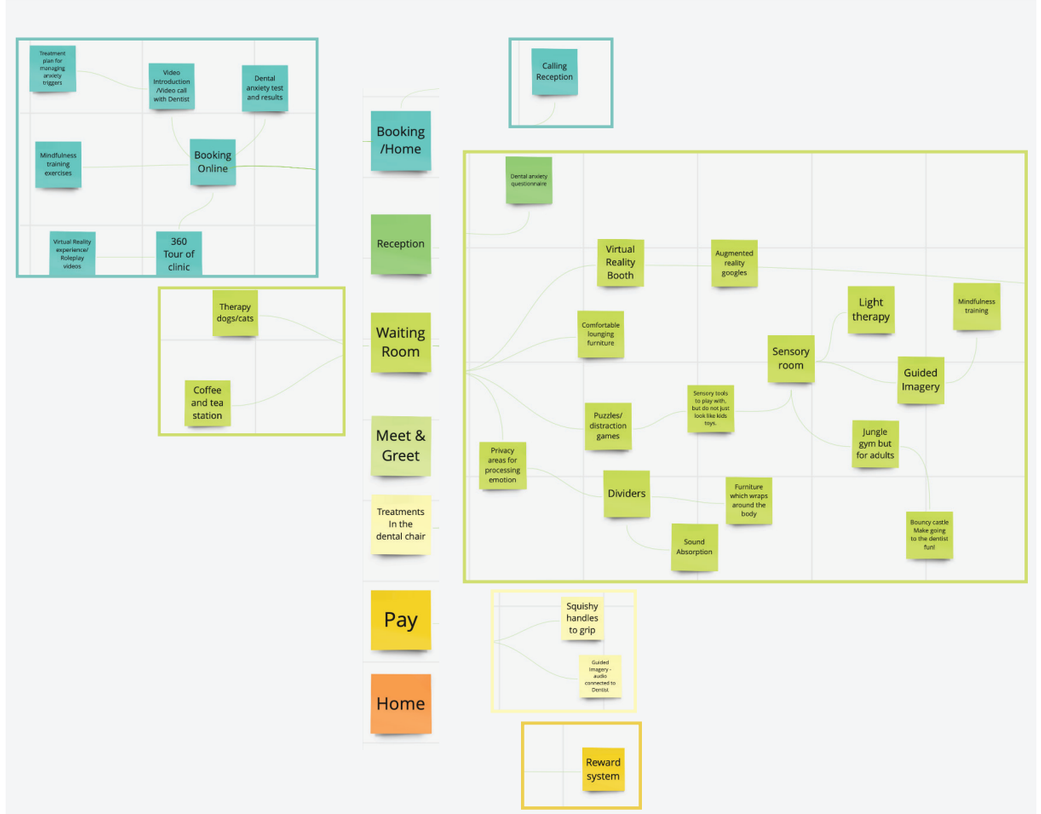
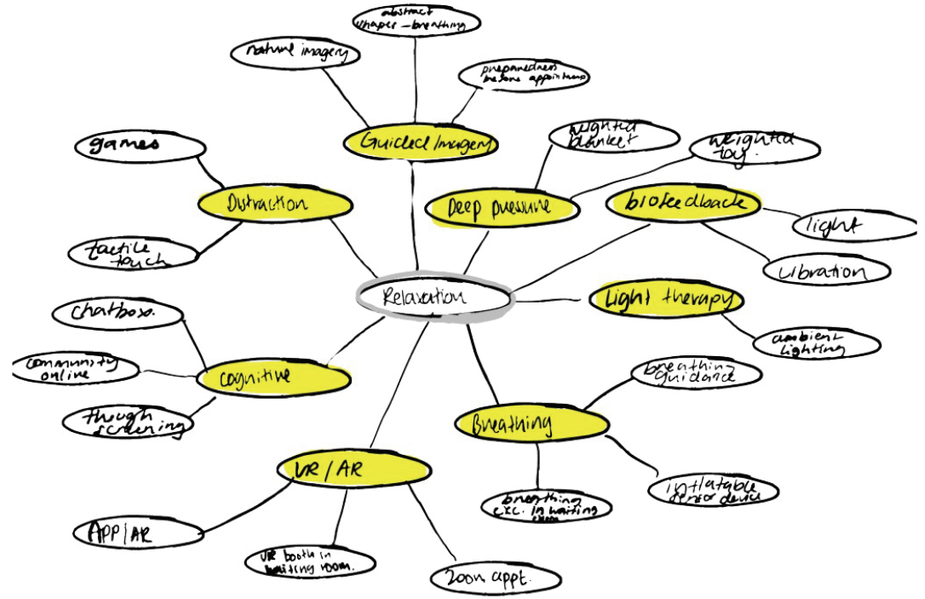


Figure 17. Brainstorming potential interventions for reducing anxiety in dental patients at stages of a typical dental care service. These stages and the interventions I assigned to them are marked by different colours.

The expense of dental treatments also places a heavy burden on patients. Although it may not be directly related to the patient dental experience, financial worry is a significant reason for patients not accessing dental care when they require it, except in emergency situations (Murad, 2020). Hence, I thought of a particular reward system as a form of positive reinforcement to encourage patients to revisit the clinic, for example discounts offered to patients who attend regular check-ups.

I used this exercise as an approach to initiate the ideation phase of my research. I had not yet interacted with participants. As a result of this brainstorm, I noticed the number of ideas I generated were higher in areas I labelled ‘Booking/Home’ and ‘Waiting Room’ (refer to figure 17). At this phase of my design process, I recognised the waiting room provided more opportunity for exploration because patients would not yet be confined to the dental chair where they experience a very limited range of motion because they are often lying down facing the ceiling.



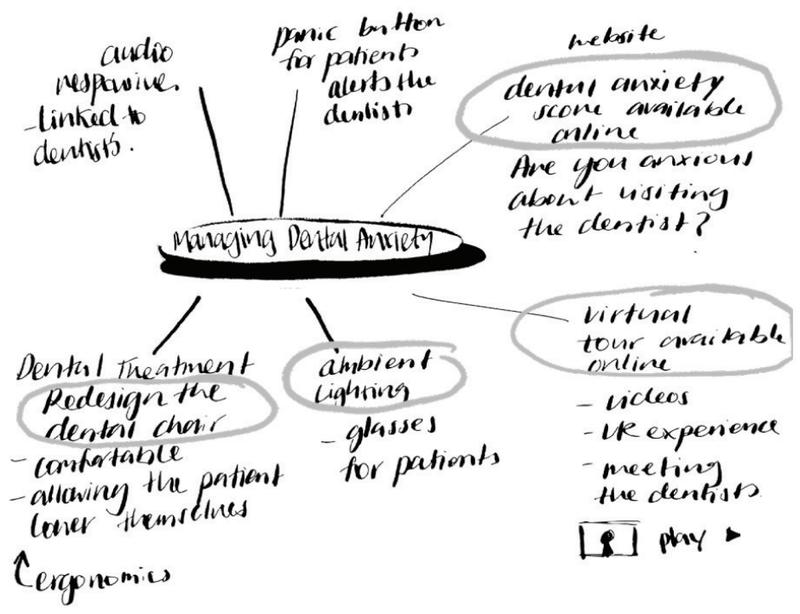


Figure 18. Brainstorm reflections.

Exploring the Potential of Mindfulness to Support Patients Toward Self-regulation and Greater Self-awareness

To be mindful means being conscious in the present moment, being aware of your body, attitude, and perceptions of the world around you without judgement. Mindfulness is not only a state of mind, but a meditative practice inspired by Buddhism, proven to diminish perceived pain and anxiety (Saei Nia, 2021) (Da Silva, 2022). My interview with the expert participant, psychologist Luke well versed in the philosophy of mindfulness, revealed potential strategies for relieving anxiety associated with dental treatments.

A patient may not be able to tap into the full benefits of mindfulness in the short span of a dental appointment. So, the mindfulness exercises need to be specifically tailored to dental care environments. Exercises must be easy to learn and effectively and quickly reduce anxiety in a short period. Luke and I discussed mindfulness techniques such as self-acceptance, self-compassion, deep breathing, and body-scanning. These concepts will be explained below.

Self-compassion captures three main ideas; “self-kindness versus self-judgment”, a sense of “common humanity versus isolation” (that “suffering is universal”), and mindfulness over catastrophizing when faced with an uncomfortable situation like receiving dental treatment (Neff & Germer, 2013, p. 1) (Luke, mindfulness expert). Self-compassion prompts an internal reflection about the human experience. For example, the sense that no one is perfect, and failure is a part of life (Neff & Germer, 2013). Furthermore, we are not always aware of peoples’ suffering around us because they might not always be showing it. Hence, we assume that we are the only ones challenged and overestimate our suffering compared to others. An example of this thinking related to dentistry could be, “I’m so anxious, I feel sick. Why is this so hard for me? I’m only getting my teeth checked and cleaned!” Practising self-compassion means reshaping our internal dialogues, for example, “I am not the only one that finds this challenging; it’s okay to be frightened. It’s okay that I need help to cope with this situation.” Self-compassion could be used in the waiting room, to make the waiting environment a space patients can utilise to mentally prepare themselves before receiving treatment, instead of a space of dread and worry. This mindfulness technique could be prompted by audio guided meditations or simple easy-to-follow paper card instructions.

Anxious patients may tend to cancel or delay appointments due to their anxiety. Self-acceptance helps to counteract the urge to avoid fearful situations, to essentially “face our fears” (Luke, mindfulness expert). An example of an internal dialogue could be, "You are here now, you're getting help, these people are well-meaning, you're sitting in this clinic, they're not only there to make money… they also want to help you…I can't avoid it.” (Luke, mindfulness expert). However, practicing self-acceptance in the waiting room could exacerbate feelings of dread and hopelessness, having the opposite desired effect. This technique might be more beneficial for patients before they attend their dental appointment to minimise cancellations due to fear and avoidance.

Body-scanning means mentally scanning the body and tune focus inwards, taking notice of any stored tension and discomfort in the body and accepting it. A user may start from the toes, “I’m feeling a sensation in my left foot” (Luke, mindfulness expert). Then, the user might move slowly up the body, pinpointing areas that are sore. The next step is to acknowledge the pain, unpack why they are experiencing the sensation, and accept it. This could prompt an internal dialogue like, “What is this sensation? And why am I feeling it.” “Much suffering comes from pushing [the pain] away as opposed to sitting with it,” said Luke (Luke, mindfulness expert).

An example of a product inspired by the mindfulness technique ‘body-scanning’ is the ‘Soma Mat’ (see figure 19). The mat integrates heating to guide users to ‘body-scan’ and encourage ‘meditative bodily introspection’. Sections of the mat heat up at programmed intervals to cue users to focus on which body parts are heated. Users can listen to audio guides to further drive them to body-scan (Ståhl et al., 2016). An excerpt of the audio script featured the following utterances: “Does your body contact the floor, right? Now your heels, your right heel? Left heel? Is there any difference between how they contact the floor?” (Ståhl, 2016, p. 3).

Regarding how this approach could apply to dentistry, I thought about an electronic cover for the dental chair. A cover which worked similarly to the ‘Soma Mat’ to guide body-scanning in the dental chair (see figure 20 on page 56).

However, in the interview, Luke acknowledged that not everyone may be open to learning these techniques. For example, patients may think: “This is just mumbo jumbo to me; I don’t like this,” suggested Luke (Luke, mindfulness expert). Therefore, he proposed mindful breathing as a potential mindfulness technique that more people may be receptive to because it is less philosophical and perhaps easier to understand, since we all breathe. Mindful breathing facilitates users to centre their attention to their breath and feel how each exhale and inhale effects their body’s physiology (Ping Lei, 2021).

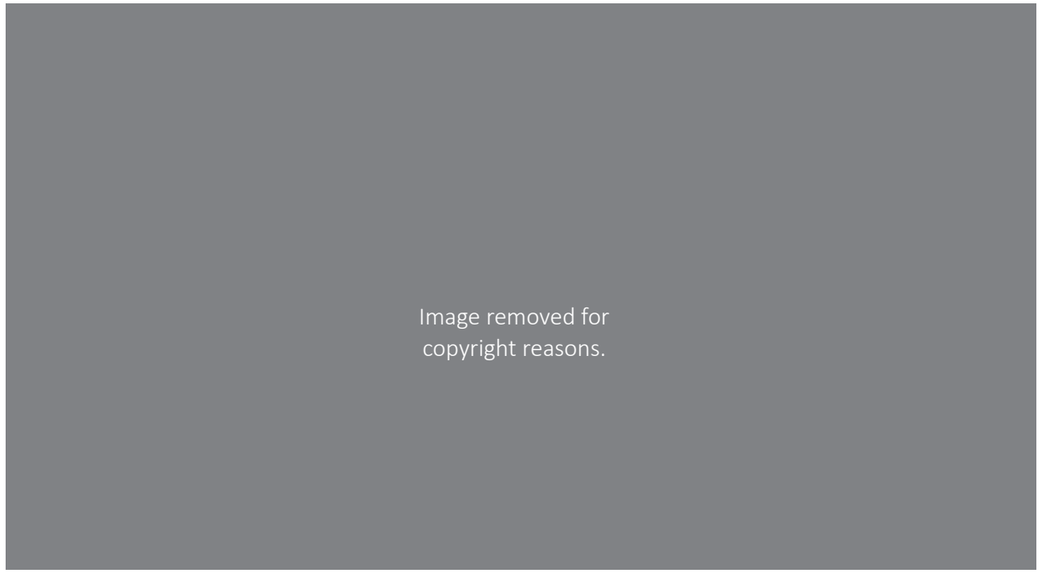


Figure 19. Soma Mat', an interactive mat to support users toward mindfulness technique body-scanning. From "The Soma Mat and Breathing Light" by Ståhl, A.,2016, p. 306-307.

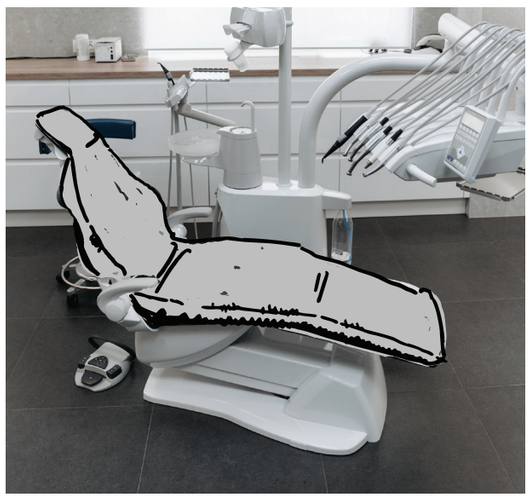


Figure 20. An electronic dental chair cover, which applies heat to different body parts at various times to assist in the mindfulness technique 'body-scanning'.

The 'Breathing Light' uses light to support uses toward mindful breathing. Light radiates from the 'Breathing Light', increasing and decreasing in intensity with every exhale and inhale from the user and encourages slower and fuller breaths for relaxation (Ståhl, 2016). Long tassels drape around the head and chest region of the user to black out potential distractions from the surrounding environment (see figure 21). The light uses an distance sensor to measure the distance between the chest and the sensor, indicating the rise and fall of the chest due to inhales and exhales (Ståhl, 2016).

Figure 21. Breathing Light' to support users breath awareness and deep breathing for relaxation. From "The Soma Mat and Breathing Light" by Ståhl, A.,2016, p. 306-308.

This section has discussed mindful exercises that might be appropriate for the waiting or consultation rooms. These two locations tend to be associated with different expressions of anxiety in patients. In waiting rooms, patients may ruminate on past trauma and catastrophize, an exaggerated negative mindset caused by anticipating real or painful experiences. Thus, mindfulness exercises that support users in regulating their thoughts and encourage positive and affirming internal dialogues like self-compassion and self-acceptance techniques may significantly affect patients in the waiting room. In contrast, patients may experience sensory overload from dental-related stimuli or physical discomfort during dental treatment. On the other hand, exercises like body scanning to support muscle relaxation may be more beneficial in the dental chair, alongside breathing techniques to regulate the nervous system.

Dental Anxiety Questionnaires

An idea I kept circling back to throughout this phase of ideation was exploring better methods for screening patients before treatments to identify a patient's level of anxiety and what specific triggers heightened their anxiety. My interviews with patient participants helped me to identify the varying causes of dental anxiety in patients. Although the physical manifestations were similar (e.g., breathlessness, churning stomach, shaking, rapid heart rate etc.), patients' experiences that contributed to them developing anxiety varied markedly. Examples are the fear of needles, of being unable to swallow or breathe correctly, as well as feelings of breathlessness or of losing control. Acknowledging how patients experience dental anxiety and what actions or sensations heighten their anxiety could facilitate dental practitioners to make changes to the treatment. I sought to find ways of helping practitioners connect with the patients and become aware of what fears or actions worsened their anxiety.

Dental anxiety questionnaires are considered reliable ways of assessing patients' levels of dental anxiety. However, these questionnaires are often poorly implemented in practice. A recent study in Japan found that only 9.7% of dental practitioners used dental anxiety questionnaires to measure their patient's level of dental anxiety. 89.1% of practitioners claimed they identified phobic dental patients based on a patient's complaints of fear of treatment. However, 73.3% of practitioners agreed that a better way to treat patients was needed. In addition, patients who received behavioural therapy as an intervention to help them manage dental fears also completed a questionnaire (Ogawa, 2022). Therefore, suggesting that patients who cooperate without complaint during dental procedures yet experience dental anxiety may not be granted access to interventions like behavioural therapy because their dental practitioner does not identify them as having high dental anxiety.

The Dental Anxiety Scale (DAS) is the most widely used dental anxiety questionnaire. The DAS consists of four questions that describe hypothetical dental conditions, rated from one (no anxiety reaction) to five (severe anxiety reactions), or from "'Relaxed' to 'So anxious that I sometimes break out in a sweat or almost feel physically ill'" (Svensson, 2020, p. 424). The results of the test range from four (no anxiety) to 20 (extreme anxiety). A DAS score of 13 or higher denotes dental anxiety, while a score of 15 or higher denotes severe dental anxiety (Svensson, 2020). Another form of a dental anxiety questionnaire is the Modified Dental Anxiety Scale (MDAS), which follows a similar structure (Svensson et al., 2020). It comprises a series of five questions based on hypothetical scenarios but includes an additional question about local anaesthesia. Additionally, the Dental Fear Survey (DFS) is a far more comprehensive yet time-intensive way of measuring levels of dental anxiety (Svensson, 2020). This survey consists of 20 items and measures the level of dental anxiety from one (no anxiety) to five (high anxiety). The test covers anticipatory anxiety, avoidance of physiological arousal, fear or specific stimuli, and a more generalised question about a patient's anxiety (Svensson, 2020). The results vary from scores of 20 to 100. Dental anxiety is frequently indicated by a total score below 60, while a score above 70 typically characterises severe dental anxiety (Svensson, 2020).

I endeavoured to find better ways to implement these dental anxiety questionnaires into practice or in a format more accessible to patients and practitioners. After all, it is crucial to identify anxious patients so that discussions can start early about how dental practitioners can support patients by providing methods for helping them manage anxious feelings regarding dentistry.

I explored the idea of an online portal (see figure 22) for patients to complete a short dental anxiety questionnaire to assess their level of anxiety while sharing what triggers their anxiety with their dentist. Patients and practitioners could then work together to navigate these challenges (see figure 23).

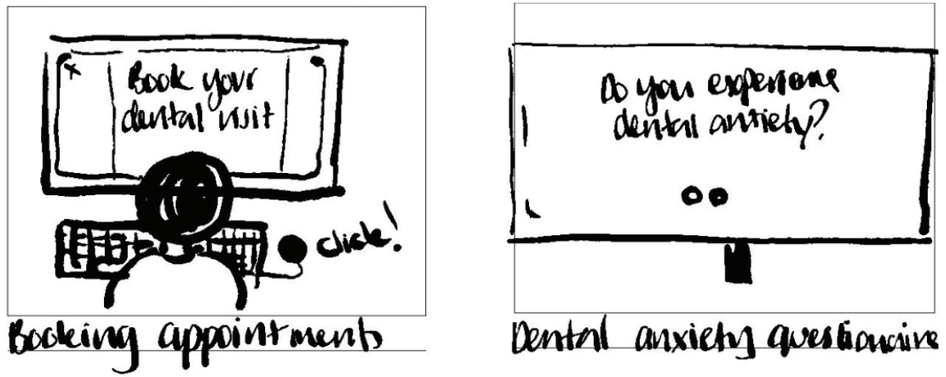


Figure 22. Design concept of an online portal for patients to complete a dental anxiety questionnaire to share with their dentist.

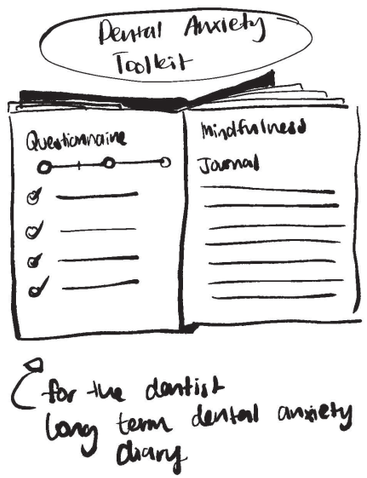


Figure 23. A "Dental Anxiety [booklet]", a toolkit which might pair with a device or product as secondary means of understanding a patient's experience with dental anxiety. The physical booklet for patients, which could feature a space to journal and a section with tips and guidance on how to practice mindfulness.

I also recognised that biofeedback technology could be used to indicate a patient's levels of distress to clinical staff and dental practitioners to provide a more comprehensive outlook on a patient's level of emotional arousal related to their dental anxiety. For this purpose, I explored ways ECG electrodes and monitors could be attached to objects like a patient's coffee cup as they sit in the waiting room before receiving treatment or on the clipboard used when signing into the clinic or registering as a new patient (refer to figure 24).

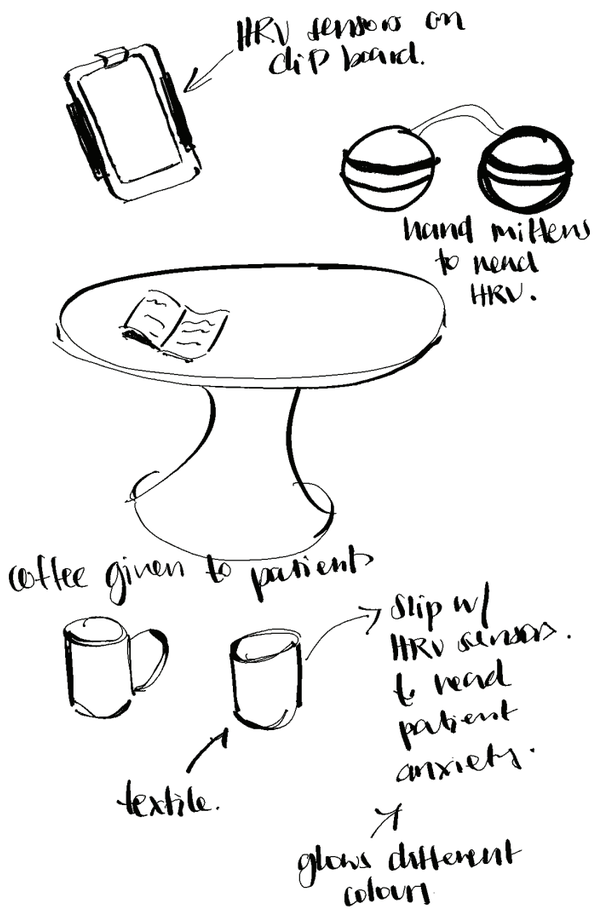


Figure 24. How ECG monitoring might be applied to everyday objects situated in the dental clinic's waiting room. For example, coffee cup sleeves or a clip board with ECG sensors attached.

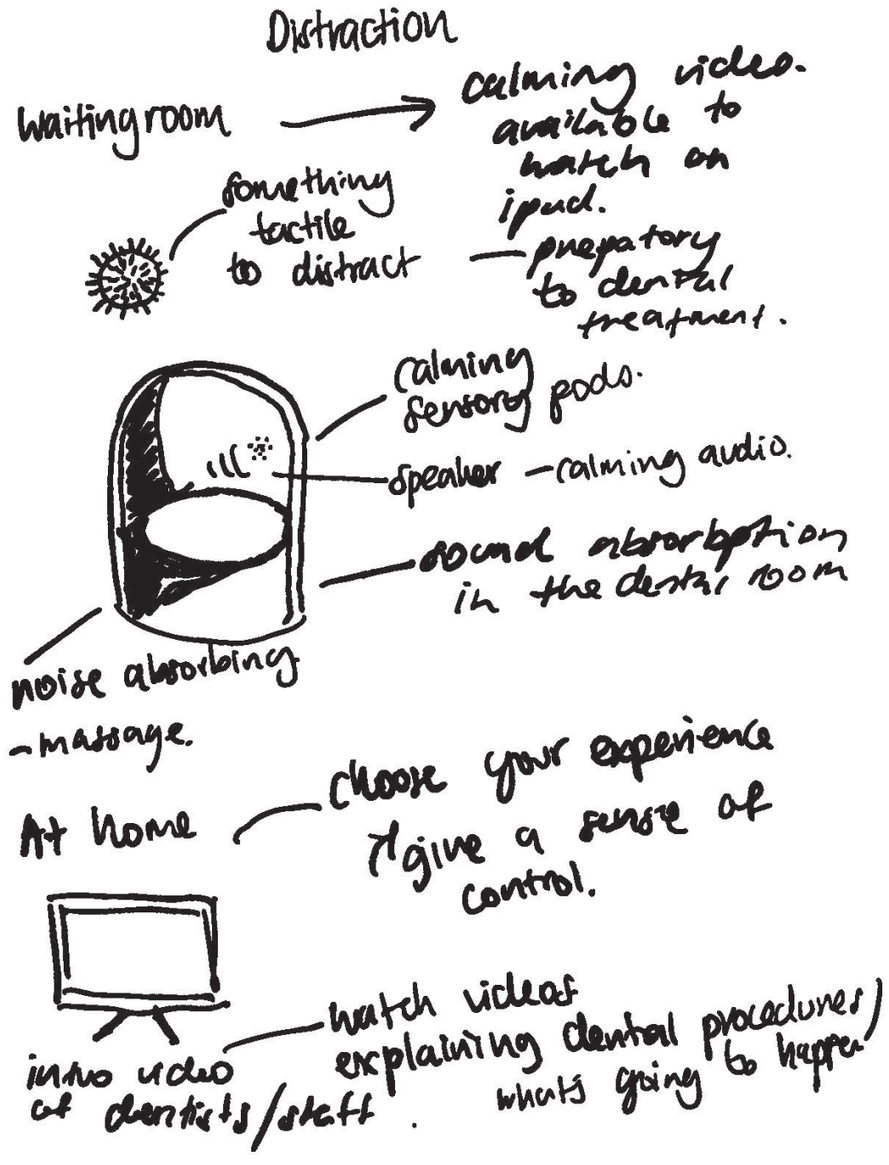


Figure 25. Ideas for the waiting room. I explored noise-cancelling booths for patients to sit and listen to calming audio.

Exploring Methods of Applying Deep Pressure for Relieving Anxiety in the Dental Chair

I explored the idea of a heatable weighted shoulder wrap to apply deep pressure to the chest, offering relief from chest tightness. The proximity to the neck, an area sensitive to touch, prompted me to consider using smooth silk-type materials that might provide added comfort. After testing a prototype on myself, I noticed it pulled on my shoulders if I did not position it correctly and shifted as I lay down or sat up. However, the weight of it on my chest did provide some relaxation. I also feared that the weight of it on the chest might interfere with breathing. I later explored applying deep pressure to the chest and stomach without contacting the neck, such as a weighted dental bib (see figure 28). Dental bibs are often used as a barrier to protect clothing from water or other liquids spurting from dental equipment during procedures.

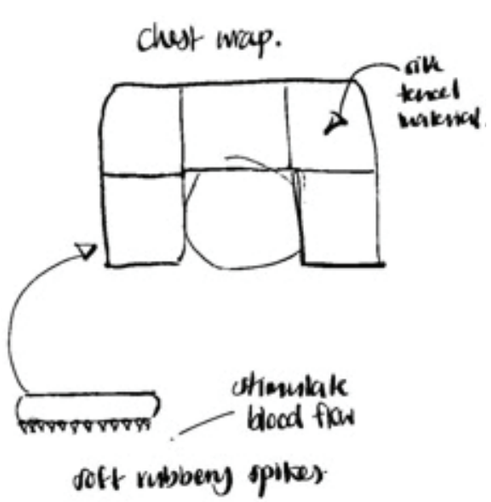


Figure 26. A Weighted neck and shoulder wrap, applying deep pressure touch and warmth for relaxation.

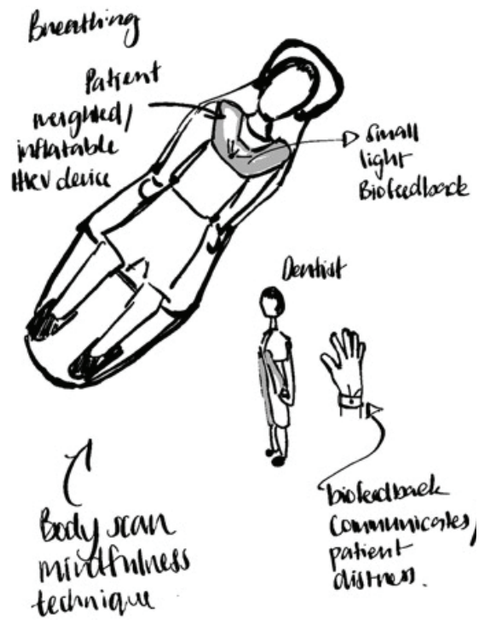


Figure 27. Sketch showing how a weighted chest and shoulder wrap could be used in the dental chair and record ECG data.

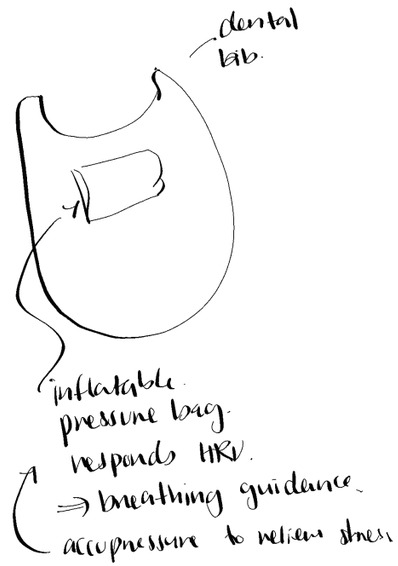


Figure 28. A weighted dental bib, which provides guided breathing by inflating and deflating.

Visually Immersive Biofeedback

In my contextual review, I acknowledged how calming visuals could help provide a calming atmosphere, such as nature imagery or slow-moving and rounded forms, like in the notorious ‘Lava Lamp’. From my own experience accessing dentistry for treatment, it was not uncommon to see a Television (TV) screen mounted to the ceiling, providing a distraction for patients during treatments. Hence, it led me to think about a biofeedback device which provides visual feedback in the form of calming abstractions, suggestive of an ECG reading but translated in a non-confronting way that the patient can easily interpret (refer to figures 29 and 30).

Emma, a patient participant I interviewed, shared how a clinic she currently visits for treatment has successfully implemented a TV for visual distraction. She described the dental clinic as “more like a beauty therapy place…they have a video screen. It’s all videos of beautiful places and scenery and nice relaxing music. It’s not advertising anything. It’s not telling you anything about dentistry. You just kind of relax and forget.” Emma’s account demonstrates how visual displays can effectively reduce patients’ anxiety.

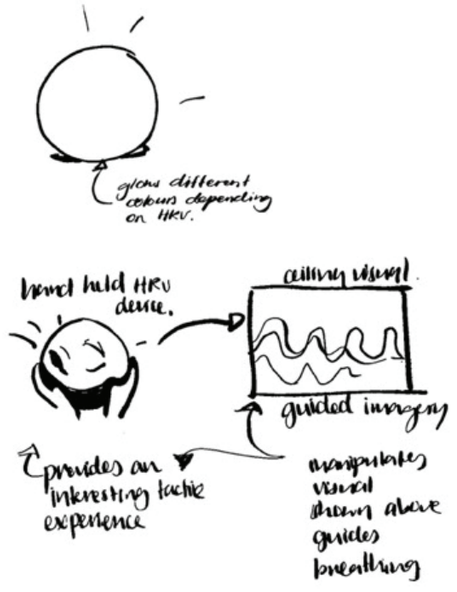


Figure 29. A sketch of a handheld device, which captures ECG data to provide visual feedback in the form of undulating wave structures, mesmerising to the eye as a form of visual distraction that shifts with the patient’s mood (HRV). Waveforms could also help guide the user’s breathing, with each peak and fall representing an inhale and exhale, respectively.

Figure 30. Exploring the use of visual biofeedback combined with breathing techniques and guided imagery to calm users.

Gamified Biofeedback and Virtual Reality

I also explored the idea of gamified biofeedback, a responsive system which challenges users to self-regulate to reach a new level in the game or achieve a goal. The idea is motivated by the therapeutic approach of positive reinforcement and resilience training and aims at patients associating high HRV with a reward. There has been some success with gamified biofeedback training, for instance the mobile app ‘Breeve’ which delivers biofeedback-based guided breathing (Center for Digital Health Interventions, 2022). However, dental appointments are often short, leaving little time for patients to improve gaming scores. Therefore, I felt it would be an inappropriate intervention for helping patients manage their anxiety. It may also increase stressors due to the potential frustration the game might provoke when players lose during the game.

I also toyed with the idea of virtual reality, an interactive three-dimensional simulated environment, to transport users through guided animations or as a form of exposure therapy. Exposure therapy is a technique therapists use to help people break a cycle of fear and avoidance by confronting their fears in a controlled environment (American Psychological Association, 2022). Nakarada-Kordic (202) found VR simulations were helpful in mentally preparing patients for MRI scanning. However, patients required multiple sessions of VR exposure therapy for the intervention to be effective (Nakarada-Kordic, 2020). Therefore, in terms of treating dental anxiety, it may be an impractical and time-intensive solution.

Products like ‘Flowly’ are commercially available to help users build self-awareness through biofeedback and VR to cope with anxiety, stress, and phobias (Flowly, n.d.). Some studies have also explored using VR in the dental chair as the ultimate escape to relax in an otherwise unpleasant situation (Cunningham, 2021; Kumari., 2021). However, commercially available VR headsets are too large, making it difficult for dental practitioners to execute dental treatments. Further research also needs to be done to confirm the efficiency of VR in reducing anxiety (López-Valverde, 2020). I also felt that they could become so immersed in the virtual world that they become detached from reality and dependent on VR to cope with their anxiety rather than working to solve the underlying problems causing their anxiety. For these reasons I did not pursue the idea of VR further, also because I felt it was outside my scope of expertise as a designer.

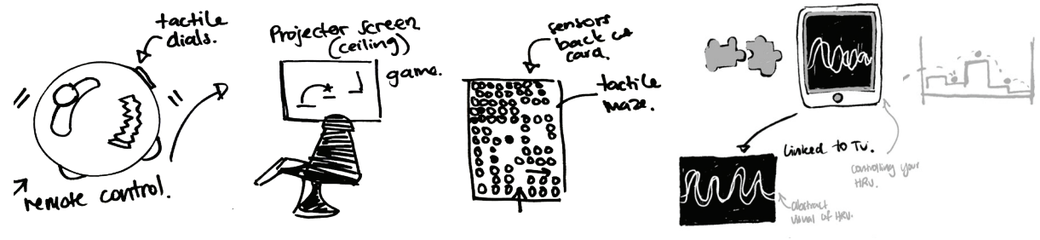


Figure 31. Gamifying Biofeedback.

Thematic Analysis:
Mapping Patient Journeys

In my interviews with patient participants, we co-constructed what I called 'Patient Journey Maps'. These maps helped structure the interviewing process and made patients' experiences visible at a system level. I documented the patient's retelling of thought processes and physical symptoms they experienced while accessing dental care services. These maps also helped me construct themes from my collection of participant data. For instance, it was important that the dentist listened to their concerns and respected their needs (refer to figures 32, 33 and 34 on pages 67 to 69).

Because these interviews were during Covid-19 restrictions, conducted via Zoom while using the online brainstorming tool, I assisted patient participants by documenting what they would have answered. I had intended to present participants with a printed copy for them to write and draw on to map out their dental care journeys. Instead, I created a key to indicate where patients felt most anxious according to the different phases of a dental appointment. For instance, if patients felt mildly anxious, moderately anxious, or very anxious (refer to figure 32 on page 67).

Initially, I intended patients to mark with pen and paper on a drawn representation of a male/female body, where in their bodies they experienced the most discomfort (e.g., tightness in the chest), like the mindfulness technique body-scan (refer to Appendix A). I tried to execute this method of recording data in a virtual setting via 'Miro' but was unsuccessful due to technological barriers. Only one of the journey maps demonstrates the use of this feature (refer to figure 34 on page 68).

An observation I made during my interviews with patient participants was how eager they were to share the stories of their previous dental care experiences with me. Yet, they were less inclined to voice their concerns and complaints about their anxiety to their dental practitioner because they felt ashamed or a burden.

The maps were a success and ensured I gathered all the necessary information to gauge how each participant experienced dental care services differently. I also think these 'Patient Journey Maps' could be improved and modified for future research to better gauge how patients experience dental anxiety. For this research, I structured it in a less intimidating format to prompt insightful discussions and reflections instead of just ticking boxes.

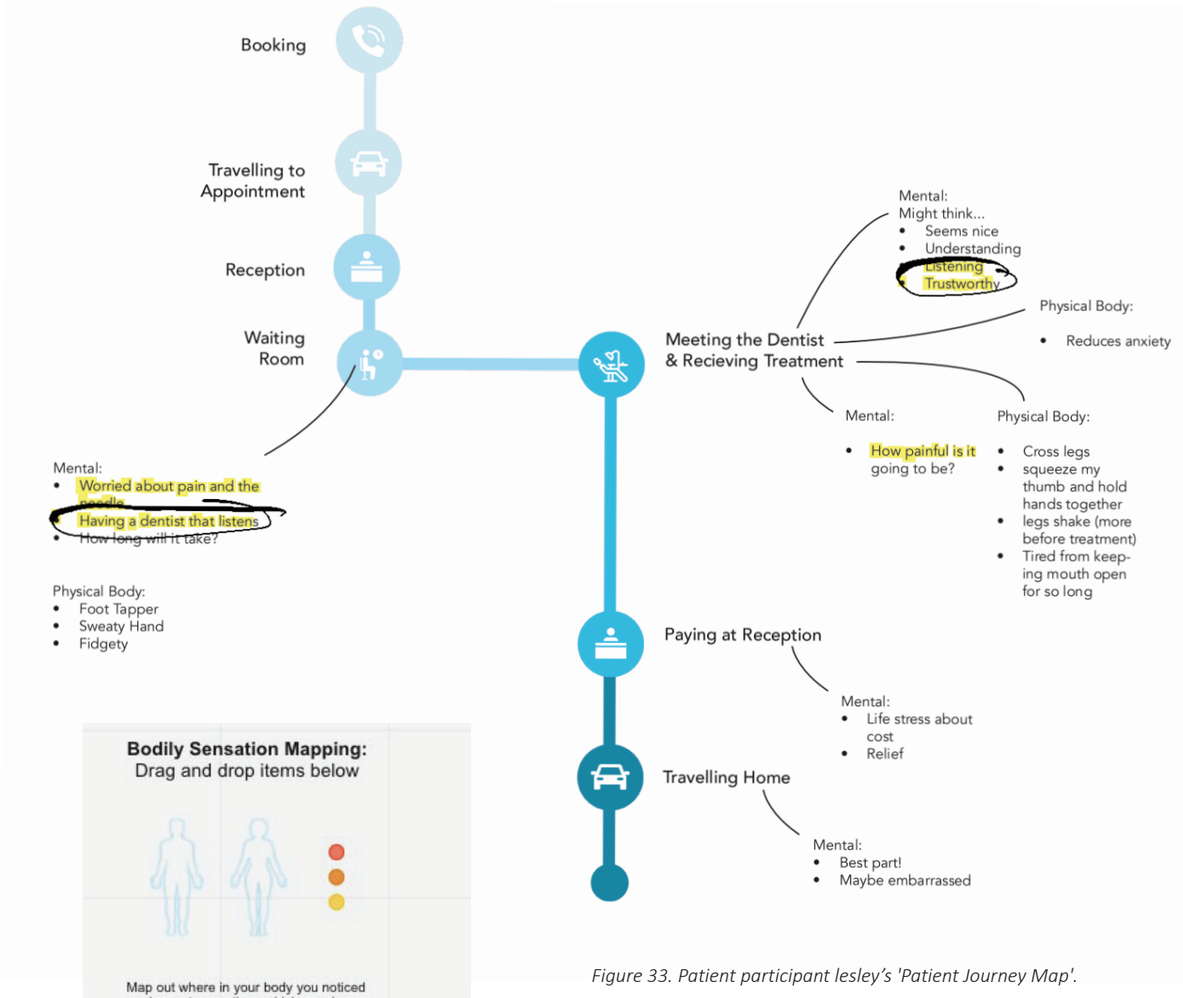


Figure 33. Patient participant lesley's 'Patient Journey Map'.

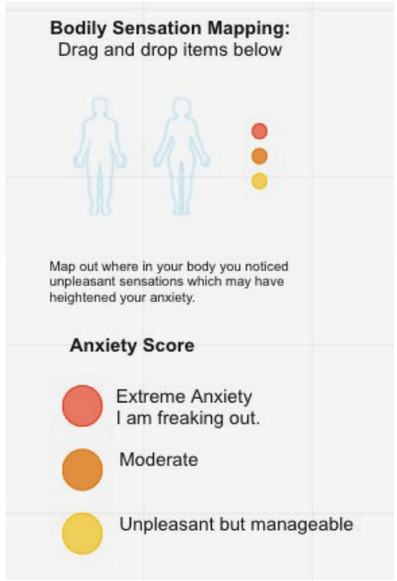


Figure 32. Key to gauge the severity of a patients' dental anxiety.

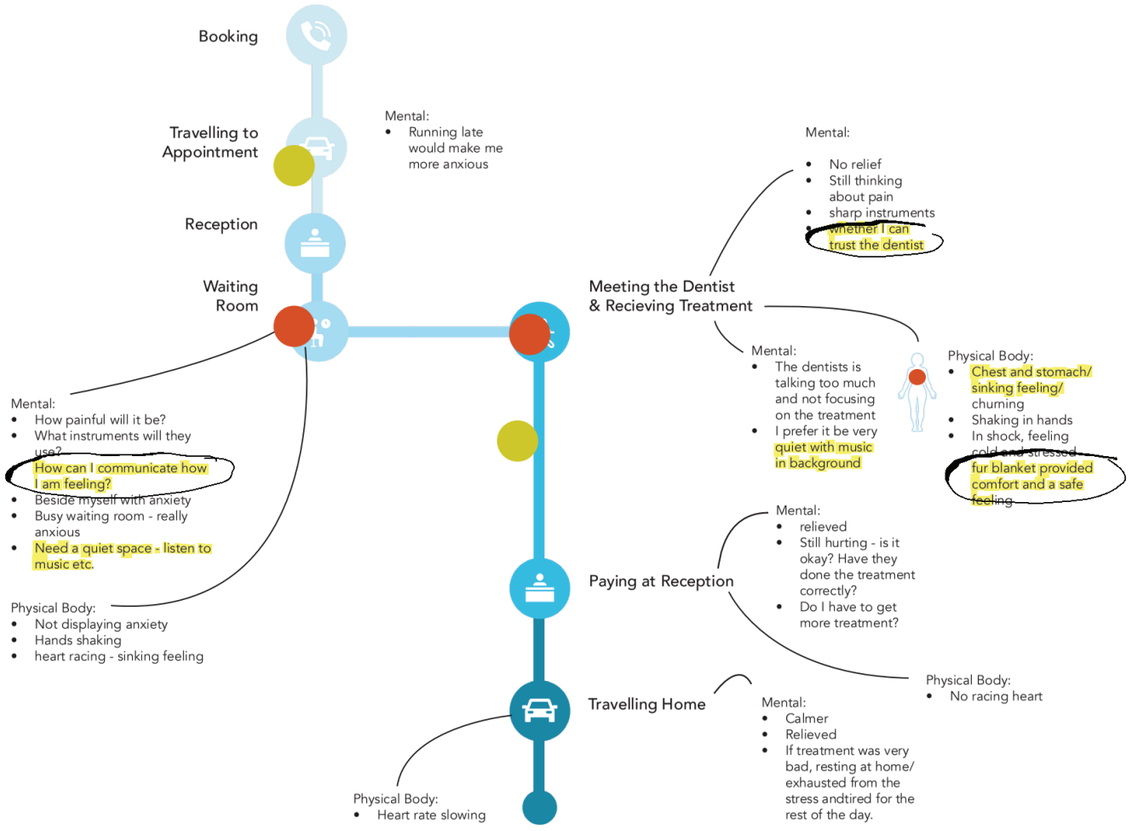


Figure 34. Patient participant Emma's 'Patient Journey Map'.

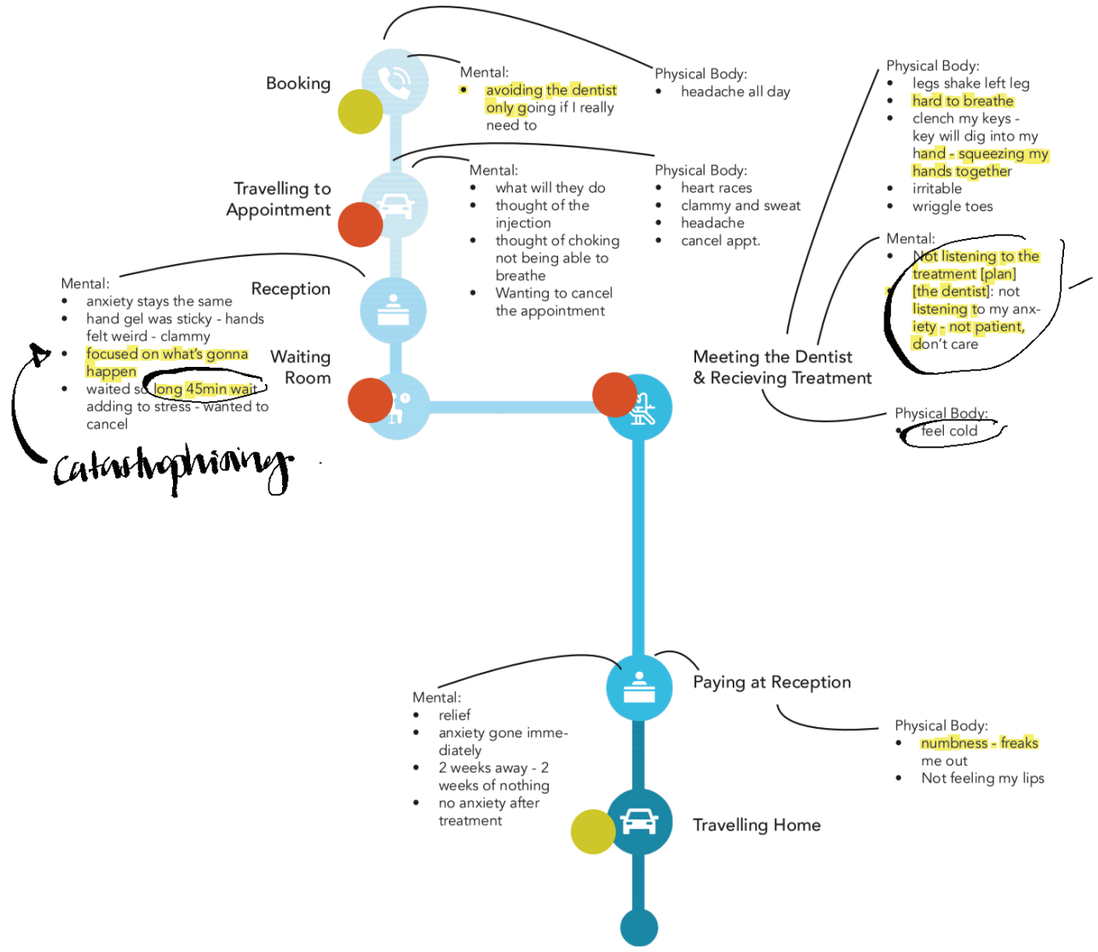


Figure 35. Patient participant Ellen's 'Patient Journey Map'.

To reflect on the information, I had gathered I collated some of the quotes I documented from patient interviews into a brainstorm, which helped me gain a better perspective of how many ways a patient can experience dental anxiety (refer to figure 36).

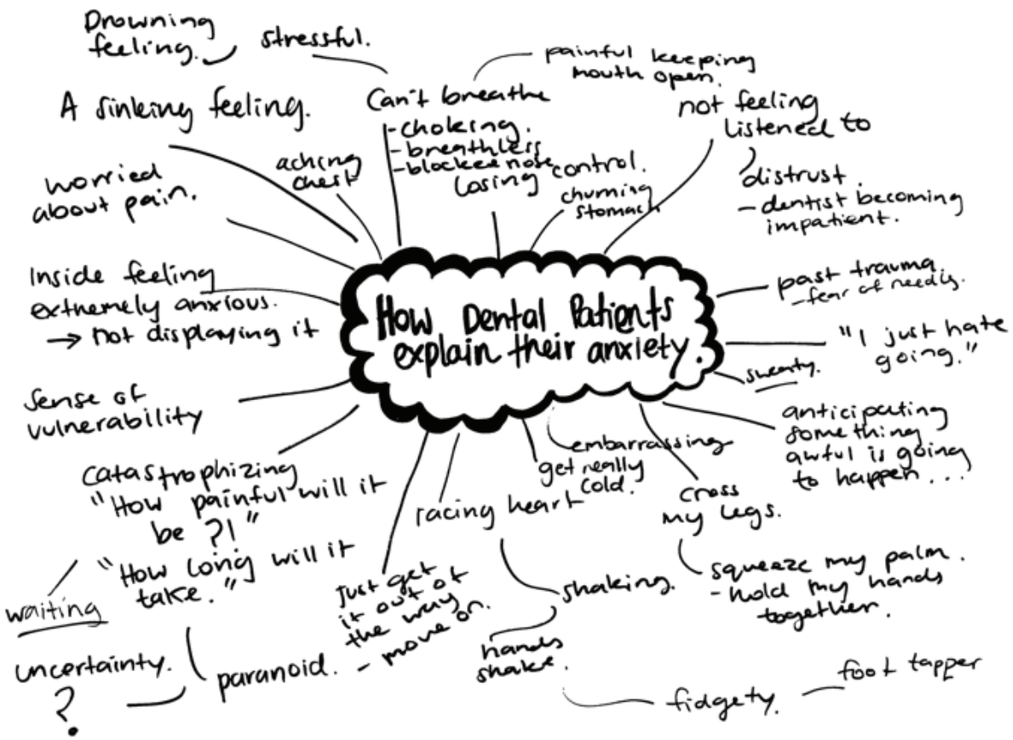


Figure 36. "How Dental Patient's [Described] their Dental Anxiey" brainstorm - reflecting on data gathered from interviews with patient participants.

Thematic Analysis:

Listening to Patients' Needs and Building Trust

"This is the problem", said Andrew, a dentist proficient in using dental anxiety questionnaires. The 'problem' is that practitioners assume that if their patient is not displaying any signs of severe distress, they are not experiencing high anxiety. Often, when dental practitioners realise the severity of their patients' anxiety, they are mid-procedure and cannot help them, such as adjusting what types of equipment are used. For example, when they are cleaning a patient's teeth, they cannot swap from machine-based to manual cleaning halfway through the treatment.

One of my patient participants, Emma shared,
"inside, I'm feeling extremely anxious. But yeah, not displaying anxiety, but inside I'm feeling [emphasis on feeling] extremely anxious."
Emma was referring to being in the waiting room to receive treatment. Based on my interview with Emma, I speculate that Emma experiences high dental anxiety despite using a validated dental anxiety questionnaire. Although Emma felt "extremely anxious", she did not display any signs of anxiety that might indicate to others that she was highly anxious.

Patients I spoke with also shared that sometimes their dentist "didn't care" and were anxious and worried they would not listen to their needs or concerns. Patients also shared that they sometimes felt like a burden and a nuisance while receiving treatment because their anxiety interfered with the dental procedure.
"She [the dental operator] really got quite annoyed that she had to keep stopping. And I just couldn't help it. At one stage, I felt like saying, 'Well, look, I've had enough. Leave it, leave it,"
said patient participant Lisa. How well dental practitioners listened to their patients was a significant factor in how patients trusted their dentists. Thus, the feeling of being able to trust their dentist helps patients feel safe.

Providing Care Options for Patients

The fear of losing control is related to feelings of not being listened to by the dental practitioners. Māori and whanau patient experience leader Andrea talked about her positive experience as a dental patient. The dental practitioner providing her care gave her options such as,
"what flavour, topical cream did I like or prefer? Did I prefer manual or machine-based cleaning? Because for some people, that continuous buzzing sound can cause headaches. I'm allergic to lots of pain medications, so getting rid of headaches is a major for me. So, my dentists were mindful and considerate," said Andrea.
Providing patients with options to modify the treatment to minimise uncomfortable sensations helps build trust between patients and practitioners.

Furthermore, different sensory modulation techniques may have other effects on patients. That is why ‘Snoezelen multi-sensory environments’ are so successful because they support users to explore different methods which meet their individual sensory needs. Such a multi-sensory environment could include a weighted blanket for some or slow and calming rhythmic music for others. This means that it is key to design a selection of products that patients could choose from in order to give all patients the chance to overcome or minimise their anxiety and relax during treatment. However, as I continued my research and idea exploration, I decided to focus on one device which could be used in different ways and adapted to suit each patient’s needs.

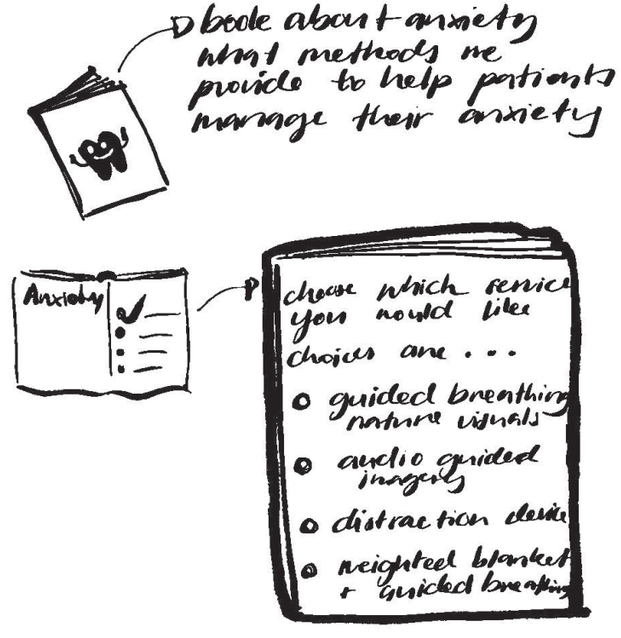


Figure 37.An information booklet for patients, explaining what options patients have to help them manage their anxiety.

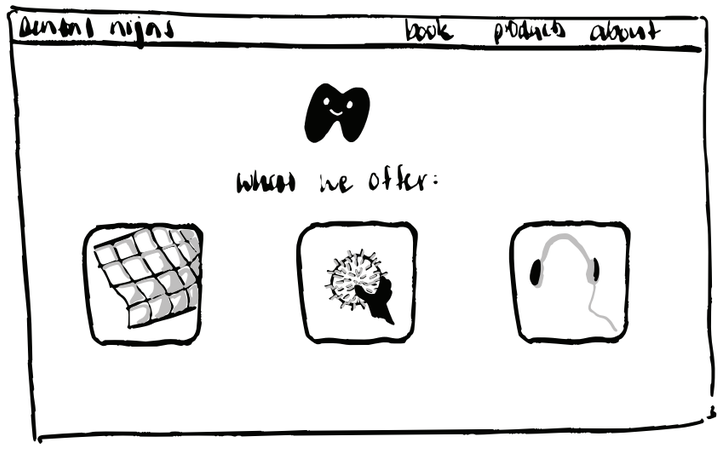


Figure 38.Website interface design that allows patients to choose which type of intervention they would like to use in the clinic before they arrive for treatment so that clinical staff can prepare necessary equipment and patients know what to expect.

Thematic Analysis:

How Time Pressures Impact How Dental Practitioners Respond to Anxious Patients

I identified time as a significant barrier which makes it difficult for practitioners to identify and respond to their patient's dental anxiety. "There's no money for talking to somebody [patients]; they [dental practitioners] only get paid if they do something. If they do a filling, if they do a crown, if they do a root canal. They only get paid for that," said dentist Andrew. In other words, dental practitioners have limited time to talk to patients. They are urged to complete procedures on time to not delay following appointments. In between seeing patients, practitioners are required to fulfill administrative tasks from the last appointment as well as sanitise the dental chair and ready equipment for the next patient. Often practitioners are so busy fulfilling these tasks that they do not have time to formally meet their next patient until they enter the dental operating room. As a result, patients miss out on their dentist taking the time to introduce themselves and ease any worries or concerns before they can become overwhelmed with anxiety while waiting in the waiting room. This lack of time devoted to understanding patients is often interpreted by patients as a lack of caring. "Get it done [the dental procedure]. Off you go. You know, and they have no time to really consider how you were feeling," said patient participant Emma. However, in many cases, patients would prefer to spend more money if that meant they had more time to feel like their worries were respected and acknowledged by their dental practitioner.

The fear of losing control is a common reason for a person's dental anxiety. Being unable to communicate distress during procedures exacerbates this fear. "Being out of control is, yes, huge for me. I've been sedated for two of the things. Hearing what's going on and not being able to talk properly absolutely freaks me out. Yeah, loss of control," shared patient participant Ellen.

Thematic Analysis:

The Effectiveness of Non-verbal Distress Cues

I recognised good communication between the practitioner and patient, whether nonverbal or verbal, was essential for building trusted patient-practitioner relationships. As discussed in the contextual review of knowledge, dental practitioners are encouraged to build rapport with their patients. However, maintaining two-way communication during procedures is very difficult in most circumstances. Often, during operations, dental practitioners are intensely focused on the mouth, meaning they lose parts of their peripheral vision that would otherwise pick up if their patient is distressed. Oral therapist and Hygienist Sandra shared a method she teaches patients as a non-verbal cue for patients to communicate distress or discomfort. "Well, I think it's probably a common thing... anyone in the dental field working in the mouth, we sometimes can get so focused on what we're doing in treatment, because it's very tactile sensitive, that we stop paying attention to our surroundings. Yeah. So, it's very hard for me to pick up on some signs if I'm just focused in that zone. And I can't [don't] have like a very wide peripheral vision. And for that reason, I say, "Put your hand up", because it's like a major signal for Yeah. And I do actually stop and listen to what's going on, manage it and go from there," said Sandra.

These examples of non-verbal communication from the patient to the dental operator, 'Put your hand up if you need me to stop' were mentioned by several of my patient and dentistry expert participants. However, sometimes it can be challenging for patients to communicate distress this way, especially when they are already overwhelmed, feeling breathless or tense. This inability to share and show pain heightens the feeling of lost control, thereby increasing anxiety and fear. When a patient does put up a hand, there are few options for them to relax and ready themselves again to go on with the procedure. Examples are putting the dental chair up, letting the patient rinse their mouth, and taking a few deep breaths. However, as I mentioned, dental practitioners are pressured by time constraints, and a more extended treatment causes delays, which means an increased wait time for following patients.

I recognised biofeedback technology as a potential method of communicating a patient's level of distress to dental practitioners as an alternative to a dental anxiety questionnaire, or as a type of system to alert the practitioner when a patient is feeling highly distressed during a procedure.

Thematic Analysis:

Difficulties Breathing: Signs and Symptoms of Emotional Distress

A key theme I constructed based on my participant interviews was how breathing affected patients. For example, some of the patients I interviewed said they experienced problems swallowing, breathlessness, and difficulty breathing through the nose instead of the mouth.

I interviewed patient participant Lisa, who experiences high dental anxiety. She complained of breathless, worsened by a medical condition, asthma. She mentioned that breathing exercises did not help to calm her:
“I do have asthma. It seems to affect my asthma. It makes me breathless. That's one of the reasons when I get to the dentist, I can't breathe that well. I just have this awful feeling, even though I do all these different strategies that you know, deep breathe in, and try and calm yourself down. It doesn't work for me.”
Patient participant Emma also shared that she experienced trouble breathing which only increased her feelings of panic:
“…I think it’s the thought of not being able to swallow… When they put the suction or anything in my mouth… Anything that goes anywhere near my throat, I start panicking immediately because they keep saying breathe through your nose and I have trouble breathing through my nose… So, I start panicking because I’m trying to breathe from [through] my mouth and it’s sucking whatever it is out of your mouth, and it panics me.”

The nature of working in the mouth makes breathing already difficult for patients because they are limited to only breathing through their mouth. However, anxiety and panic make these situations worse. As described earlier in the contextual review, our sympathetic nervous system (SNS), the ‘fight or flight response, kicks in when we feel anxious or threatened (Everly & Lating, 2013). The activation of the SNS constricts airways and raises the heart rate, which contributes to breathlessness (refer to figure 4 on page 17) (Everly & Lating, 2013). In addition, an overly reactive gagging reflex during procedures is associated with anxiety, potentially causing feelings of “drowning” patient participants mentioned experiencing (Randall., 2014).

These factors make breathing even more difficult for patients in the dental chair. This feeling of not being able to breathe panics patients, making them feel powerless, which prompts them to catastrophize even more as they might think “I’m going to die”. This feeling of overwhelming panic and heightened emotional arousal makes it very hard to think clearly and deescalate feelings.

As I expected, most of the dental participants mentioned they were familiar with using deep breathing techniques. However, they did not explain how they supported patients to exercise deep breathing. The dental practitioners also shared that they supported anxious patients by pausing the procedure and encouraging them to take a few slow deep breaths to calm down. “We just let them sit up [and] have a few deep breaths. They might drink some water in between the session just to have a breather,” said dental therapist and hygienist Sandra.

Deep diaphragmatic breathing is proven as an effective way to stimulate the vagus nerve and activate the parasympathetic nervous system (‘rest and digest’) (Levi et al., 2022). During inhales the diaphragm contracts, and relaxes during exhales, acting as a sort of vacuum pulling in air . As a result, the abdomen expands and shrinks with every breath in and out. It has been shown that sustained exhalation results in a decreased heart rate and helps people to calm down (Hamasaki, 2020). Hyperventilation (rapid breathing), which is what patients experience when they become panicked and breathless, can lead to lower levels of carbon-dioxide in the blood and result in symptoms like chest pain, light-headedness, and a disoriented feeling (Meuret & Ritz, 2010). This happens because the ‘fight and flight response’ kicks in when we experience physical or emotional distress. The neck and upper chest muscles (secondary muscles to the diaphragm) take over to ventilate the upper chest. This is what often causes chest pain due to anxiety because of the prolonged use of these muscles for breathing (Hansen, 2022). Therefore, telling patients to take a “deep breath” may not give clear enough instructions to ensure patients are activating the diaphragm. For example, place one hand on the chest and one on the abdomen and slowly taking in breaths making sure the abdomen is rising and not the chest, signalling that the diaphragm is activated.

Personal Reflection on Deep Breathing
Reflecting on my own experiences with stress and anxiety, I, like some of the patients I talked to sometimes feel so overwhelmed that I disregard deep breathing, for example, I may think “Oh that’s not going to work, it’s useless.” However, when I pressed a hot water bottle to my abdomen while lying down, the deep weighted pressure and heat from the water bottle pulled my attention toward my breath, and I felt it was easier and more natural to want to take fuller breaths using my diaphragm to pull air into my lungs.

Exploring Methods of Providing Breathing Guidance with Touch

As mentioned in the contextual review, repetitive motions, like stroking or finger tracing, can be soothing (Snoezelen Multi-Sensory Environments, 2022). Interesting textures provide sensory distraction. I explored forms that might help patients practice mindful breathing, such as a spiral shape which supports users to trace their fingers inwards in the spiral(breathing out) and trace them outwards again (breathing in). The repetition and familiarity of these motions provide a sense of calm (refer to the top right-hand side of figure 39). The waveforms displayed follow a similar idea: tracing the fingers over the forms to guide breathing simultaneously.

Figure 39. Mindful breathing through tactile interfaces.

Thematic Analysis:
Recommendations and Insights for Interventions

Dentistry Experts

Dental experts shared that distraction was a method they commonly incorporated into their practice. Examples of how they use distraction includes tapping the patient on the shoulder as they administered a local anaesthetic. Other strategies involve offering patients a hand to squeeze or presenting them with a task like finding the ‘Wally’ [cartoon character] in the ‘Where’s Wally?’ poster above their heads or asking them to wriggle their toes. “They [the dental clinic] had this big map on a tile, so that while the dentist is talking to you, they [the dentist or dental assistant] can ask questions to distract you like, “Hey, can you find the…? A ‘Where’s Wally?’ type thing,” said patient experience lead Andrea. Oral therapist and Hygienist Lauren, who also specialises in treating patients with special needs, said she now uses essential oils to mask unwanted dental-related smells, like the smell of antiseptic substances.

Patient Participants

Patients shared positive dental care experiences and interventions which significantly reduced their anxiety. The interventions mentioned include videos of calming scenery situated above the dental chair for patients to "relax and forget" (patient Emma) (expert Andrea), a fluffy blanket draped around them in the dental chair (Emma), or a heated blanket (patient Tabitha).

Emma recounts that the dental practitioner providing her treatment put a "mohair blanket around me. I felt really comfortable…it was just lovely to have that feeling around me, [the warm, soft, and luxurious feel of the mohair blanket]." I introduced her to the idea of a weighted blanket, which she had never used before. "You've given me some ideas about the weighted blanket. I'm going to look into that," said Emma. Other participants, I interviewed also showed interest in a weighted blanket, such as dental therapist and hygienist Sandra. Patient participant Tabitha mentioned that after undergoing emergency dental treatment, their dentist gave them a heated blanket, which helped them relax. Even though it was a hot summer day, the warmth from the blanket was comforting. "I was very weak, just the feeling of the warmth and weight of it…. I think a lot of people would respond to that sort of thing," said Tabitha.

These solutions, the "mohair blankets" and "heated blanket", stood out to me because of the positive effect they had on Emma and Tabitha's experience. I also recognised the potential to enhance these interventions.

Sensory Distraction:
Exploring Different Tactile Interfaces

I gathered a series of objects with interesting textures I thought might help distract patients away from negative thoughts. The objects I chose included spiky objects or rough textures to feel and touch (see figure 40 and 41).

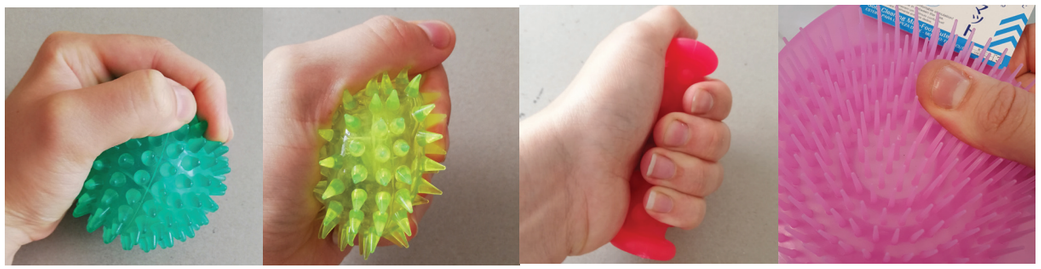


Figure 40. The hard and spiky textures provide a sense of grounding. The jabbing of the blunt plastic spikes against the palm could offer an effective way of refocusing pain away from the mouth.

Figure 41. Fine detailed textures for distraction.

An Ideal World in Dentistry: Reflection

My interviews with patients moved me; they gave me a new perspective on dentistry, which I had never considered before. I made a wish list for dentistry, a reflective exercise from my interviews with patient participants helped me acknowledge the barriers patients face that prevent them from accessing dental care services—for instance, the monetary expense of dentistry for patients, as well of lack of trust patients may feel based on negative past dental care experiences.

I was also inspired by what whanau patient experience leader Andrea shared with me, “You’ve got to think about your most valuable member of your family. And think about how would you like someone to approach them? What would be the Gold Standard experience of dental care? What would it feel like? What would it have?” This approach to thinking about healthcare helped me challenge my own ideas about dentistry and explore what could be possible for the future.

These points are musings, a reflective exercise from what I learned from my interviews with patients and my own experiences of dental care. I do not consider most of the ideas I have listed plausible. This list was something I did not explore further. But I felt the need to make visible the things I may have never considered if I had not conducted this research project, such as the heavy financial burden which prevents individuals from accessing the care, they need to repair their teeth or to heal.

1. A time where dentistry is free and accessible to all.
2. It feels like a spa day.
3. Patients are calm and relax.
4. Needles do not hurt.
5. Dentists are under no time pressures.
6. Latex gloves taste like your favourite dessert.
7. Your dentists advise you on how to take care of your teeth from home via monthly video call consultations.
8. People value and praise dentists as essential members of society, ultimately leaving them feeling fulfilled and respected by society.
9. There are no month-long waits for emergency dental procedures
10. You can recover from having a tooth removed in half the time and receive a complimentary cool pack each time you leave the dentist to ease your pain.
11. Oral hygiene products are not taxed at the supermarket so everyone can access affordable dental hygiene products.

Documenting A Personal Dental Care Experience

Sometimes during my research, I forgot what it feels like to be a dental patient, because it is such as unique experience. You arrive at the clinic, disclose your personal information, and are whisked off to the dental operating room, where you lie down with your mouth open wide staring at the ceiling. This is an unusual position you experience maybe every year. I visited the dentist as a patient during the timespan of this master's project. This writing is a retelling of my experience.

I arrived flustered because I had gone to the wrong address and was running twenty minutes late. However, my stress slowly ebbed as I met the receptionist, and the dentist led me to the dental room. The room was light and airy, minimal, and clean. They sat me down and asked me about myself, what I did for a living, small talk, things like that. First, they examined my teeth, looking for areas that needed work. They made me feel comfortable and at ease. I laid a weighted sack filled with buckwheat kernels on my lap. It made me feel comfortable. Like I had a furry friend sitting on my lap.

I noticed my hands tensed up, and the dental therapist gently allowed me a break. They were very kind and patient, warning me when they turned on the water suction thingy that would spray and suck out the water and make a horrible gurgling noise. I looked at the bloody water being sucked through the suction tube, and I felt disgusted, and my stomach churned. I tried to focus on a small round smudge on the wall in front of me and avoided looking directly above me where I could see the dental tools. That helped. My legs were relaxed. The only parts of my body that were not were my hands, which were tightly locked together. However, I liken the feeling to when a person you trust helps you take a large splinter out from under your skin. An irrational part of you expects pain, even from the smallest of things, so you tense up; and it's hard not to. My body says, "Get me out of here; I don't like this." After the treatment, I felt good, knowing I had done a good thing for my health and my teeth were white and clean.

Biggest Takeaways:

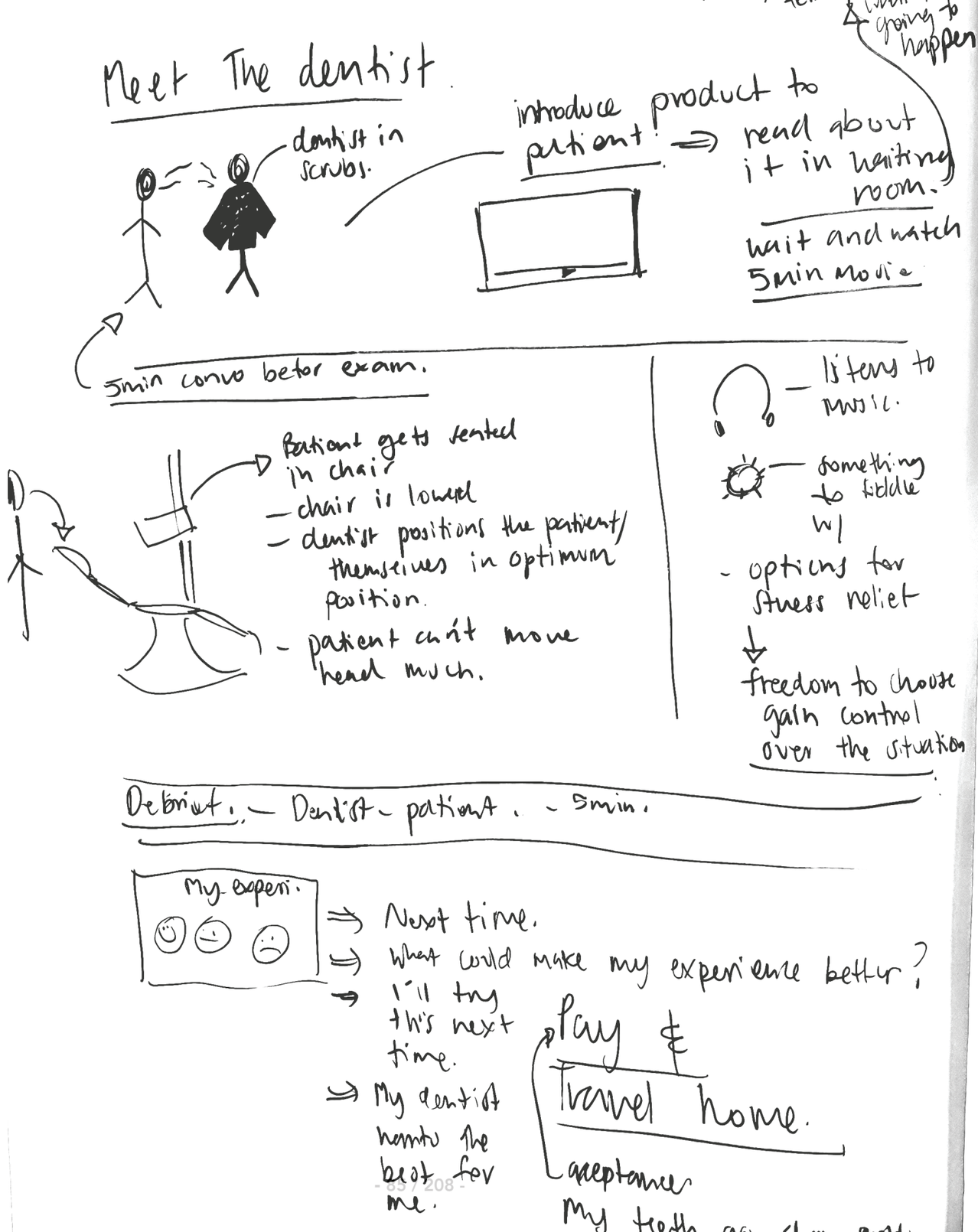
- I focused on a smudge on the wall to distract my attention from what was happening in my mouth.
- The weight from the wheat bag helped. However, a heavier weight would have had a greater effect.
- My hands were tense and unmoving
- The dental therapist was kind; they made me feel comfortable.
- I liked her choice of music; it was helpful to keep my mind elsewhere.

Discover: Key Findings

My interaction with participants helped define a direction for my project. From participant data, I constructed five key themes. These included the importance of active listening for practitioners toward building trust with their patients and the cruciality of identifying anxious patients early and time as a significant barrier for dental practitioners treating anxious patients. Furthermore, dental treatments and anxiety affect patients' breathing and distraction techniques' effectiveness in reducing patient anxiety and modulating arousal through proprioceptive senses, such as using weighted, heated, and soft fluffy blankets.

Define Chapter

At this stage of my research ('define'), I defined the direction for my project based on what discoveries I made during the 'discover' phase of my research. In this chapter, I explore the application of deep pressure touch as a potential method for relieving dental anxiety and the integration of ECG monitoring for measuring dental anxiety in real-time.



Weighted Blankets: Proprioceptive Senses

Studies have shown the effectiveness of weighted blankets at reducing anxiety in clinical settings, such as relieving anxiety in chemotherapy patients, pre-operative care, mental health, and dentistry (Champagne et al., 2015; Chen, 2013; Metro-Sanchez, 2020; Vinson et al., 2020). Chen (2013) investigated the effects of deep pressure touch on patients' dental anxiety alleviated. This study found that deep pressure touch in the form of a weighted blanket, when tested using a PPG sensor for measuring HRV and EDA for skin conducting, had a calming effect on participants due to the activation of the PnSN (Chen, 2013). The evidence to support the effectiveness of weighted blankets in reducing anxiety led me to develop better ways of deep pressure in dentistry to ease patient anxiety and integrate sensor technology for monitoring anxiety.

Dental anxiety is a complex problem, in part because anxiety manifests physically and emotionally in different ways for different people. As such, the reasons that cause patients to become anxious are seldom the same for everyone.

My contextual review revealed what weighted products are currently available in dentistry to reduce dental anxiety (refer to figures 6 and 7 on pages 20 to 21). Papoose boards, used primarily in paediatric dentistry and for special needs patients, also provide deep pressure touch. These boards are foam-padded and include four sets of Velcro straps to secure a patient's shoulders, torso and thighs firmly and subsequently offer sustained deep pressure (Chen et al., 2014). Studies have investigated the potential calming effect of these boards on patients with special needs. Chen (2014) found these boards were not harmful to special-needs patients. However, an ethical dilemma about using these devices in dentistry remains. Andrew (dental expert) greatly discourages using these devices due to the risk of heightening fear in patients. Physical restraint during dental treatments has increased dental fear and distrust of dentistry in child patients. 'Children 1st Dental & Surgery Centre' also acknowledge the potential risk of heightening anxiety in patients using forced restraint and recognise the adverse emotional effects papoosing can have on patients, which can linger in adult patients (Children 1st, 2021). Weighted blankets offer a safer way of applying deep pressure and come in various sizes and weights to suit users' needs. I speculated that a large blanket might be overwhelming for patients who fear losing control during dental treatments or have experienced emotional distress while physically restrained during treatment. For instance, a patient participant shared how she was physically restrained as a child and now, as an adult, experiences high dental anxiety, heightened by lying down in the dental chair (Lisa, patient participant). "They held me down about three or four of them and put this gas mask on my face, and it sort of stayed with me." (Lisa, patient participant).

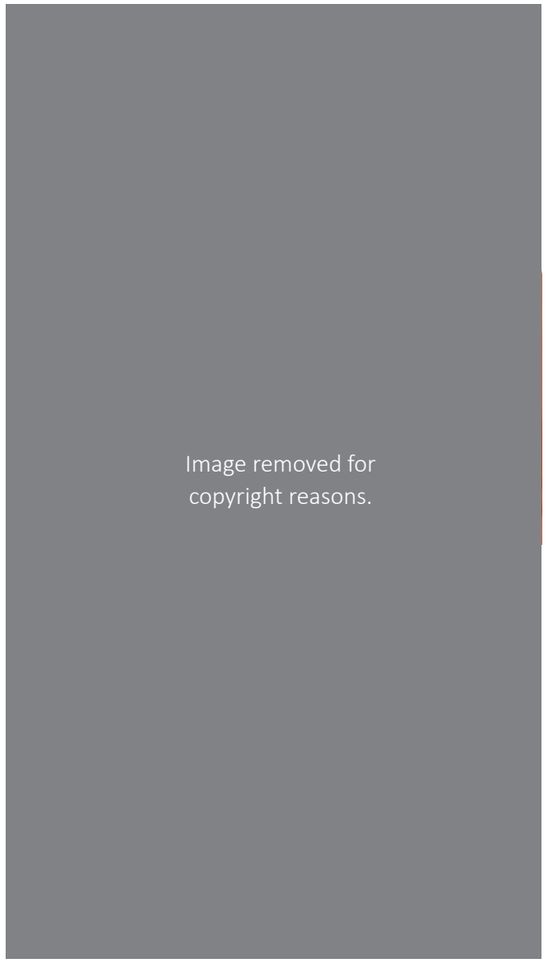


Figure 42. Papoose device for physical restraint during dental procedures. From 'Mobile Medical Systems', 2021 (https://mobilemedical.com.au/dental/rainbow-stabilising-system/)

‘CapeAble’ Weighted Blankets: Existing Product Analysis

Weighted blankets have become renowned in the consumer markets for improving sleep and helping manage stress because of their calming effects. A few brands offer various weighted blankets, which come in different materials, soft ones for at-home use or medical grade blankets more suitable for hospital or dental care environments. Dental Hygienist Metro-Sanchez (2020) wanted to test these blankets for herself and determine whether they improved her patient's experiences. She searched for high-quality weighted blankets and found 'CapeAble' weighted blankets. They offered an even distribution of weight for optimum activation of proprioceptive senses. They could be easily lifted onto patients' laps, repositioned, and conformed nicely around their bodies, staying in place during procedures. Although lead blankets gave similar deep pressure touch effects, she recognised the comfort and appearance of these weighted blankets as vastly superior. She noticed her patients’ became more relaxed and less tense when using these products. “Amazingly enough, smiles often crossed their faces. As a result, I became more relaxed too.” (Metro-Sanchez, 2020, p. 38).

‘CapeAble’ weighted blankets offer a wide variety of blankets. Their products use ‘Smart Weight’ patented technology for the best distribution of weight (see figure 43).

Figure 43."CapeAble® Medical Grade Blanket". from CapeAble Weighted Products. Retrieved 16/08/2022 from https://www.capeable.com/products/medical-grade-blanket?_pos=1&_sid=00f9069ec&_ss=r

Testing Existing Weighted Blankets

To gain personal insight into the effectiveness of weighted blankets I tested a few existing weighted blankets on myself. These included ten-kilogram lap blanket (approximately 22 by 70 centimetres) and seven-kilogram full length weighted blanket (approximately 203 by 152 centimetres) (Groundd Sleep, 2022; Sensory Corner, n.d.).

Figure 44. Positioning the weighted lap blanket on the lap width ways as well as vertically. “10kg Weighted Blanket” from ‘Sensory Corner’.

The ten-kilogram blanket from ‘Sensory corner’ (New Zealand Supplier of sensory products for management of mood and sensory processing disorders) was difficult to carry, but when I positioned it on my lap the weight was noticeable and provided a grounding effect (Sensory Corner, n.d.) (refer to figure 44). I rotated the blanket length ways to feel the weight of it on my chest. The weight of the blanket caused the blanket to slide down my torso. Although, the blanket had a calming effect, I considered the blanket to be too heavy for usage in the dental chair. A lighter weighted blanket would achieve a similar effect.

The large full weighted blanket from ‘Groundd’ (New Zealand brand and design of weighted blankets for sleep) covered me from chest to toes (Groundd Sleep, 2022). The blanket weight (7 kilogram) made up roughly 10% of my body weight, the recommended percentage from occupational therapists (Caws, n.d.; Groundd Sleep, 2022). The weight was gentle, but provided a ‘hugging’ effect associated with deep pressure touch (Krauss, 1987). Folding the blanket applied more concentrated pressure on my lap or torso. The waffle-like compartments for dispersing the weight are much smaller than the ‘Sensory Corner’s’ 10-kilogram lap blanket. Meaning, an even weight distribution over the body, which minimises pulling in areas and helps it stay in place.

Integrating Biosensing in Weighted Blankets

In terms of collecting reliable ECG sensor readings sensor electrodes could be situated on the underside of the blanket in contact with the user's torso, where ECG is often applied because of its proximity to the heart for a drawing of potential positions for sensor electrodes on the torso). Having sensor electrodes resting on the user's torso, would keep the users hands-free, providing opportunities for tactile interactions (for fidgeting) to distract patients from negative thoughts and sensations associated with dentistry (see figure 45). EDA sensors could also be situated where the user interacts using their hands to collect additional data about the user's nervous system.

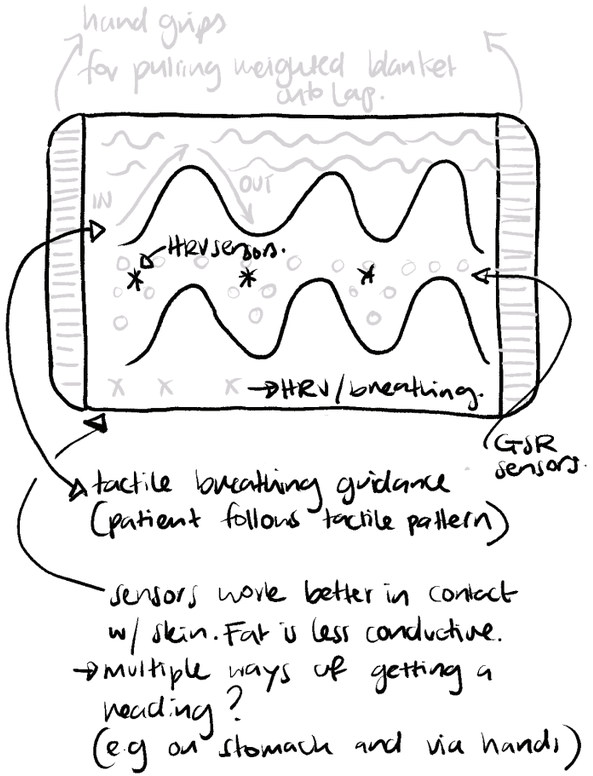


Figure 45. Sketch of weighted blanket showing where sensor electrodes might be placed. This concept features handles on either side of the device to assist with pulling and positioning the weighted blanket on the body. Wavelike texture acts as tactile cues to encourage deep breathing.

There were a few problems I recognised with this concept. For example, sensor electrodes work better when they come in direct contact with the skin (personal communication, IBTEC). If a patient wears thick clothing, the electrodes will not have enough contact with the skin to provide usable ECG sensor readings (personal communication, IBTEC). Fat is also less conductive, so ECG readings may differ from patient to patient, making readings less reliable (personal communication, IBTEC). The patient could position their clothing in a way that would allow skin contact. However, dental practitioners are under time pressure, therefore a prolonged setup time before dental procedures would increase work stressors for the practitioner. In addition, the patient may feel uncomfortable if asked to reposition or remove clothing items to allow better contact with sensor electrodes. Therefore, I decided that having sensor electrodes resting on the torso would be impractical. It would be more practical to have the sensor electrodes in sight on top of the blanket where patients could place their hands directly onto. It may also give patients a focal point or task to focus on to distract from negative thoughts.

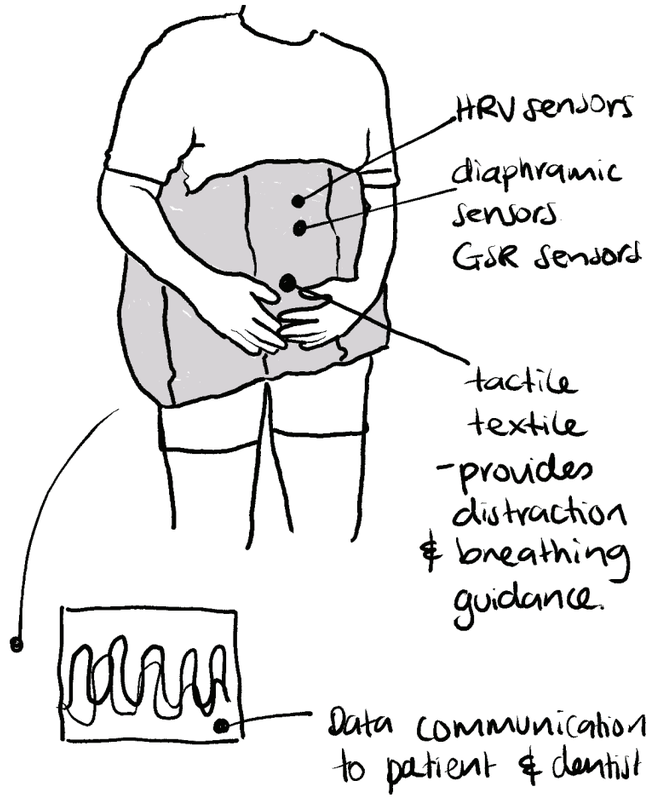


Figure 46. Drawing of weighted blanket and possible positions for HRV, Galvanic Skin Response (electrodermal activity) (GSR) sensors, and accelerometers for measuring respiration ("diaphragm sensors"). Also shows image of how the data might be visually shown to patients and or the dentist.

Roleplay: Lead Blanket

I investigated the idea of a lead blanket as a method of applying deep touch pressure to potentially utilise equipment found in clinical dental environments to reduce the cost of the design outcome and increase the accessibility of the design outcome in public and private dental health settings. Cermak (2015) investigated the feasibility of “sensory adapted environments” and used an X-ray lead blanket as an alternative solution to a weighted blanket to apply deep pressure touch to children with autism spectrum disorder (ASD) (Sharon A. Cermak, 2015; S. A. Cermak., 2015).

I visited a dental clinic to experience the clinical interior of a dental operating room and try on an X-ray vest (figure 47).

Figure 47. Image of myself wearing a X-ray protection lead blanket.

Lead blankets aim to lessen the effect of radiation exposure from dental X-rays. However, they are rarely used today because of technological advancements and rigorous clinical precautions, which have meant dental X-rays scatter significantly less radiation posing a very low health threat (HPS, 2016). X-ray vests are designed to cover the essential areas of the body most at risk of damage from radiation exposure, such as the thyroid located on the neck, critical organs, and genitalia (HPS, 2016). The lead blanket in figure 47 on page 92 weighs approximately 7 kilograms and is covered in a vinyl-type material for easy cleaning and sanitisation.

I explored the idea of using a lead blanket to provide deep pressure but design a cover which could fit over the lead blanket and make it more comfortable (e.g., a soft washable textile cover as opposed to the cold vinyl). In addition, sensors could be applied to the cover design to monitor HRV. The thought the lead blanket could be folded into the desired shape and inserted into the cover.

When I tried the lead blanket on at the dental clinic, it felt cold, and the proximity of the blanket to my neck was off-putting, as it made me feel like I was restrained.

I learned about lead blankets; if not stored correctly, cracks can form in the lead, providing inadequate protection from radiation. Therefore, if lead blankets were folded and inserted into a cover, the lead blanket would eventually deteriorate and render itself useless at protecting against radiation. Additionally, the high toxicity of lead could present as a health risk if the blanket tore (Belavgenis, 2020).

Initial Design Brief

I developed an initial design brief based on the information I gathered from speaking with participants and my discussion with IBTEC about the feasibility of my project. This initial design brief is a list of criteria I thought essential for the success of a design outcome. Later in my project once I had developed my concepts further, I outlined a secondary design brief from new knowledge I had gathered from prototyping and testing my ideas.

Key features

- Measures HRV using ECG sensors
- Is effective at reducing anxiety in a short time, supported by the literature.
- Easy to use and explain to patients (i.e., takes approximately five minutes maximum to explain how it is used)
- Communicates biofeedback data to the dentist without providing distraction or obstruction during dental treatments.
- Cost-effective, accessible to both private and public care settings. Dental anxiety affects everyone from different cultural and economic backgrounds. Therefore, I felt that it was my duty as a designer to make the product I create accessible to all clinics. For example, by utilizing existing equipment the clinic may already have or making the device multifunctional so fewer devices are needs to suit different users.
- Encourages patients to self-regulate their anxiety, for example, sensory modulation and mindfulness techniques such as deep breathing are examples of methods which encourage emotional self-regulation.

Data Communication

- TV or other electronic device mounted to the wall or other surface (not directly above patient) providing visual distraction (calming scenery and visuals etc.)
- An additional device to communicate HRV to the dentist to notify them when their patient is experiencing discomfort and high anxiety. For instance, data could be synced using Bluetooth to the dentist's existing apple watch or may be situated on dental equipment or on the dental practitioner's clothing.

Weighted Blanket/object

- Weighted blanket must be easy to transport and position on the patient's body, by the practitioner and patient.
- Must be easy to clean and taken apart. For instance, separate compartments for electronics etc.
- Have an even distribution of weight for maximum nerve activation and comfort (e.g., 5cm/5cm seamed pockets containing weighted glass bead such as in 'SmartWeight' 'CapeAble' Weighted blankets)
- Blankets could range in a variety of size from throw size to something for the lap to cover greater or smaller areas of the body.
- Could include interesting textures and additional tactile features to make the device more interactive and act as a method of distraction for patients.

The Dental Button

From my interviews, part of what caused patients to become anxious was the lack of control they felt in the dental chair. The 'Dental Button' system allows patients to stop the dental drill remotely and safely during dental procedures (see figure 48) (Dental Phobia, 2022). The security and comfort that button brings patients have resulted in a reduction of patient anxiety from between 50-80% and an increase in dentist productivity by 30%, with fewer patients avoiding appointments (Berkeley Clinic, 2021). The safety and assurance the button provides for patients mean patients rarely press the button. An excellent example of how restoring a sense of control for patients eliminates most of their fear and anxiety (Berkeley Clinic, 2021).

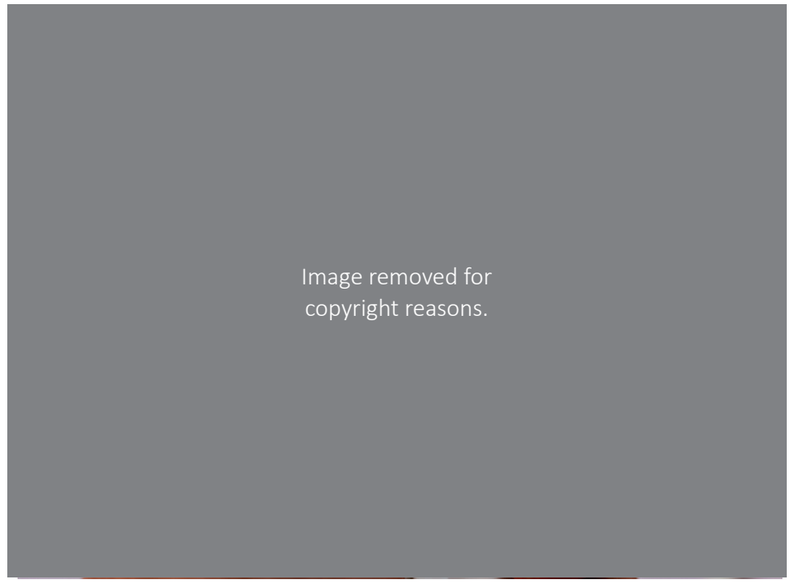


Figure 48. Image of a person about the press the red button of 'The Dental Button' a device provided to patients so they can safely stop the dental drill mid-treatment if they are experiencing pain or anxiety. "Dental Phobia" 2022 by Dental Button, from https://www.dentalphobia.co.uk/get-help/dental-techniques/dental-button/.

Methods of Communicating ECG Data to Dental Practitioners

I looked at various ways of alerting dental practitioners about their patients' distress during treatments. As I mentioned, it can be challenging for dentists to determine whether their patient is feeling highly distressed.

I explored the idea of an alert system, similar to that of ‘The Dental Button’, to provide patients with a way of communicating distress when to their practitioner (Dental Phobia, 2022). For instance, the dental practitioner might receive an alert when HRV becomes unusually low, signalling high anxiety. If was displayed visually to communicate a patient’s distress it recognised it needed to be situation int the dental operator's field of vision during a procedure. “I lose my peripheral vision” (dental expert, Sandra). Examples include an object worn on the dental operator's wrist, glasses or situated above the dental light. I thought a sound alert such as beeping would increase anxiety in patients, as these sounds are associated with other health-related devices signalling potential medical emergencies. Irritating buzzing or beeping during procedures could also become annoying during dental procedures, meaning dentists are likely to want to turn the machine off (follow-up interview with dentist Andrew). However, there might be potential to make audio feedback less intrusive and disruptive, like the biofeedback device ‘RESPerATE’, which converts HRV into musical tones to gently communicate changes in HRV (Morarend, 2011). I speculated that some sort of lighting fixture or LED situated outside the patient’s gaze but available to practitioners might be a more appropriate way of communicating a patient’s distress. However, a light too small may be confused with other lights from other dental equipment.

Another thing I considered about communicating a patient's biodata to dentists was how comfortable patients might feel sharing such a vulnerable feeling. However, after following up with patient Emma, she thought the idea would make her feel more secure and less ashamed about being anxious, knowing their dentist knew how greatly she was affected by dental anxiety. Although, if patients are asked directly at reception if they experience dental anxiety, Emma thought this might be confronting for patients, and make them question why they are asking this. For instance, they might start thinking, “Am I supposed to feel anxious? Should I be anxious. A question as simple as ‘Do you feel anxious when accessing dental care services’ when a patient is registering to attend an appointment at the dentist and then making information available about what is offered to help reduce stress in patents might help to avoid any potential awkwardness at reception because the reception will be notified beforehand that a patients feels anxious and requires an intervention or my device.

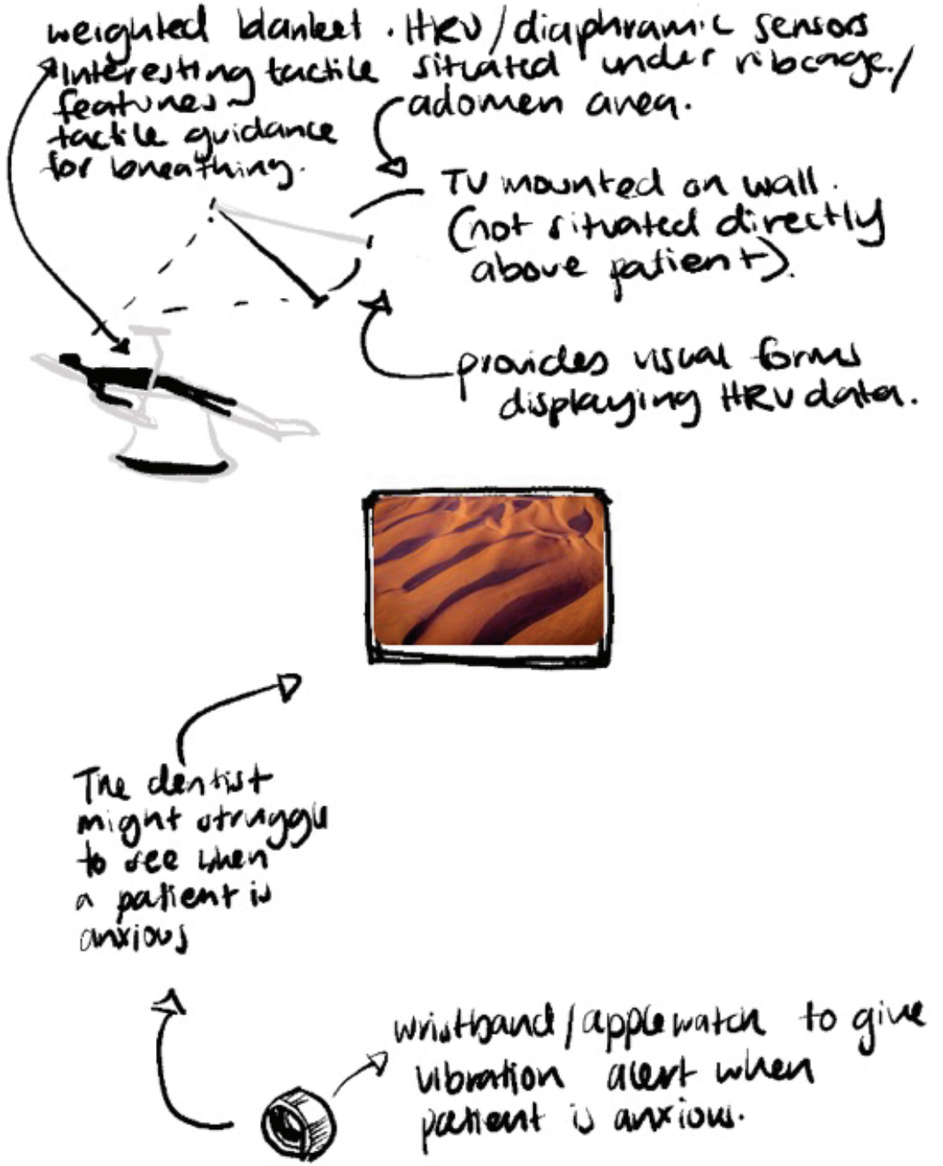


Figure 49. Brainstorm of how HRV data might be visually communicated using calming visuals and a device that alerts the dentist when their patients is highly distressed.

Figure 50. Possible forms of communicating a distress alert from patients to practitioners during dental procedures.

Realtime Data: IBTEC

I met with biotechnologists from The Institute of Biomedical Technologies (IBTec) (sponsors of this research and affiliated with AUT) about the feasibility of providing real-time biofeedback ECG data and its application in dentistry to reduce anxiety in patients. A key part of what IBTEC do is develop new technologies to “aid and enhance physiological monitoring of human vital signs and activities”. IBTEC is investigating ways to improve ECG monitoring and have developed algorithms, a data filtration system, to filter noisy data from ECG electrode, and therefore increase the potential for ECG sensing to be applied in different ways and using different conductive materials used for electrodes. This is what makes applying ECG to a weighted blanket possible. Although this project requires ongoing research to validate the use of ECG electrodes and sensors in this way, it shows the potential for new ways of applying this type of biosensing to monitor physiological arousal and behaviour as an indicator of anxiety in a dental setting.

We also discussed the benefits of collecting real-time data regarding dentistry and measuring patients’ anxiety. Although, communicating patient distress to dental practitioners using a real-time ECG feed was a solution I thought necessary to improve non-verbal cues of distress in the patients during dental procedures, we also considered the benefit of using the ECG data as measure to validate relaxation techniques used to reduce anxiety in patients, as a way of signalling whether an interventions is benefiting a patient or not, and what changes could be made to adjust or adapt interventions to create a better patient experience.

We had some concerns about whether using biofeedback in such a short period like a dental procedure may cause ore anxiety in patients if they are struggling to control their HRV in the time available.

The technical limitations I needed to consider, which were most important, how the electrodes would contact the skin and where on the body applying these electrodes would be most appropriate and result in a reliable sensor reading. I found out ECG could be taken from the palms and fingertips. However, there needed to be two points of contact; for instance, two hands must contact two different sensor electrodes and be connected separately to sensors in a circuit. To not ensure a cleaner reading (little electrical noise), hands should not contact each other while touching electrodes. 'Smart' touch detection technology could allow multiple electrodes, presenting more opportunities to interact with the device in various ways with multiple sensor electrodes because users are not limited to placing hands in one location on the device.

Summaries of Data

Dental expert and specialist for special needs patients, Lauren, mentioned that dentists sometimes keep a record of a patient's behaviour and observations they made during treatment, as well as any complaints the patients had. This record can then be shared when the patient moves onto another dentists or acts as a reminder for next time when they treat the same patient again.
"We look at the history... [There are] records that only practitioners can see and there are records that the patients and we can see. So, in the other notes [practitioner record] we might note that 'this person doesn't like water in their mouth, or 'they don't like their head to bed tipped over a certain angle' or 'being touched on the face'," said Lauren.

Before interviewing Lauren, I was not aware dental practitioners recorded patient's preferences toward treatment. This new insight led me explore how I could use HRV data to create timestamped summaries of data, which could be shared with the dentist. Identifying what moments during the treatment the patient experienced high anxiety. To unpack the reasons why they experienced dental anxiety and identify ways of improving future procedures with the patient.

Sense Checking: Follow-up Expert Interview

This interview was conducted with dentist Andrew, who had agreed to be contacted again for a second interview. The purpose of the interview was to gather feedback on the current direction of my project, a weighted sensing blanket. I developed a series of questions for Andrew, regarding practical limitations, for example cleaning the device or any other changes I could make to the dental operating environment. I also was concerned about the level of administration practitioners were willing to dedicate for using the blanket and communicating with their patients to improve their dental anxiety. The interview reconfirmed how time pressured dental practitioners were. Andrew reiterated, "You don't get paid for talking to patients." Providing them with other tasks, for example, teaching patients how to use the product, being notified when they felt anxious and reading a 'summary of results' would likely add to work pressures, making dental practitioners more at risk of burnout.

The dentist was also concerned that stopping each time a patient felt nervous would cause too many disruptions during the dental procedure. There are few options dentists can offer patients in this situation, usually dental practitioners offer them a short pause to sit up and rinse out their mouths or to take a few deep breaths as I learned from my expert interviews.

My interview with Andrew sparked some internal questions about my project which I needed to research more into to solve these problems.

Questions I started to ask myself after my follow-up interview Andrew:

- Is it essential to communicate patient stress to dental operators?
- The patient is stressed... what then?
- How do patients give consent?
- What calming effect will the device have? Is the method evidence-based?
- Would a summary of the results be useful? How so?
- How an intervention for reducing anxiety in patients be implemented without overburdening dentists with additional administrative tasks?

I started to focus on ways to design a product that would help patients regulate their emotions in the dental chair without assistance from the dentist. Examples of other possible interventions including assisting patient to focus on things they can control, such as their breathing, bodily functions, etc.

Beyond Biofeedback:
Responsive Biofeedback for Deep Breathing

I explored a series of ideas, which aimed to provide ways of calming patients, such as applying deep pressure, distraction, breathing guidance and responsive biofeedback. Therapy dogs are sometimes used in dentistry to reduce patient anxiety (see figure 51). The concept “Therapy Dog Simulation” mimics the same feeling of having a warm, fluffy dog laying on your lap (see figure 52 on page 103). The concept “Therapy Dog Simulation” is a weighted lap blanket which features a breathing apparatus that responds to HRV data to suggest longer expirations times to reduce anxiety when a patient’s anxiety becomes heightened. I was inspired by “Breathe with Touch”, which also translates HRV this way (Bin Yu, 2017).

This concept also featured a panic button like that of “The Dental Button” (Dental Phobia, 2022). I was uncertain using HRV hooked up to an alert system to notify the dentist when the patient was highly distressed would be inappropriate, because a patient’s anxiety may remain consistent over the treatment. A button which the patient could press themselves may minimise unnecessary delays during the treatment, but still ensure patients had a clear way of communicating to their dentist about their anxiety. The device could also be made from a rubber-like material which could be easily cleaned between appointments.

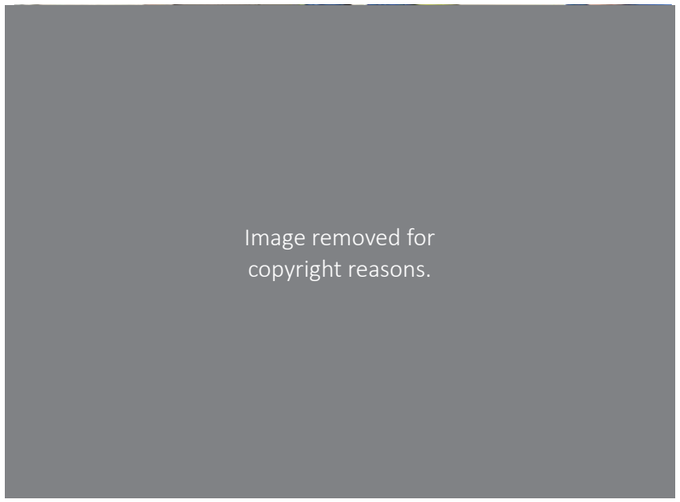


Figure 51. Image of patient with a therapy dog resting on their lap during a dental treatment. By Crouch 2022. Retrieved 16/8/2022 from https://www.washingtonpost.com/health/2022/02/26/dental-dogs-anxious-patients/

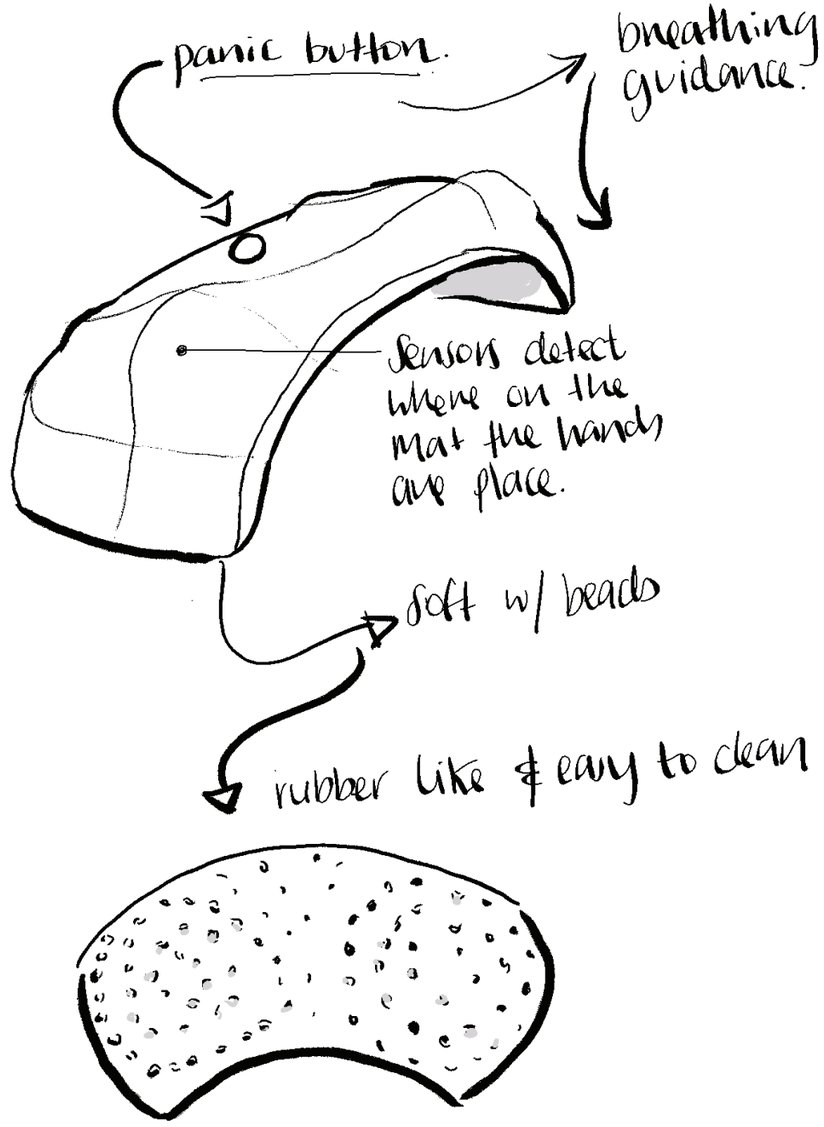


Figure 52. Therapy dog simulation.

Concept sketch of 'The Adjustable Weighted Blanket'. An adjustable weighted blanket integrated with sensors on the middle piece (covering the abdomen). Parts of the blanket ccould be detached to make it larger or smaller based on the patient preferences (figures 53 and 54).

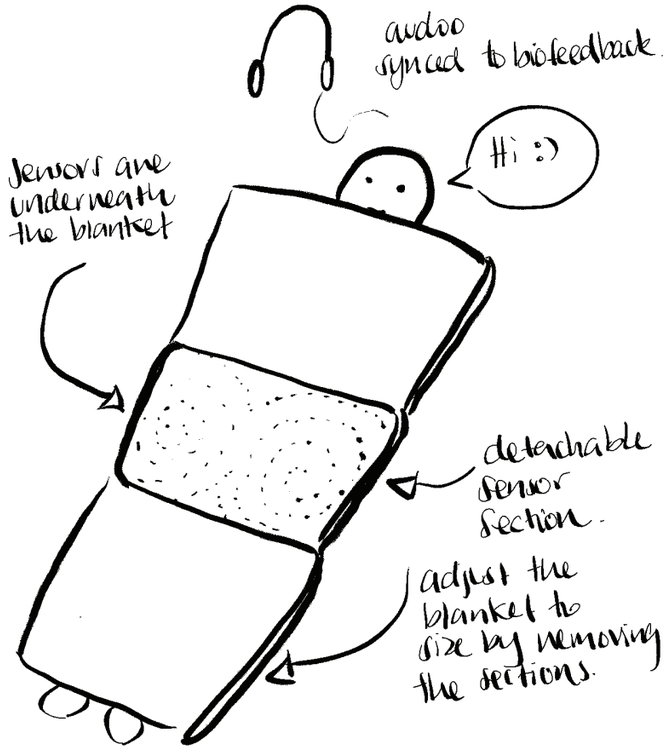


Figure 53. The Adjustable Weighted Blanket

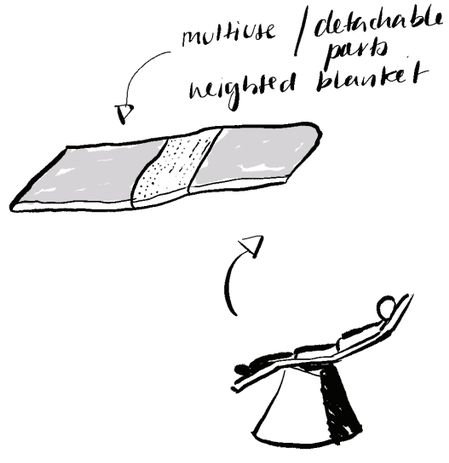


Figure 54. Side view multi-use blanket.

I explored pillow-like forms patients could clutch and squeeze to release tension, like a stress ball. However, pressure sensors could be embedded in the device to gauge how distressed a patient feels based on how much pressure they apply to the cushion. However, patients may differ according to muscle strength (e.g. how much squeezing force they can use on the pillow). Hence, the pressure threshold used to indicate a patient's distress may not be accurate for everyone (see figure 55).

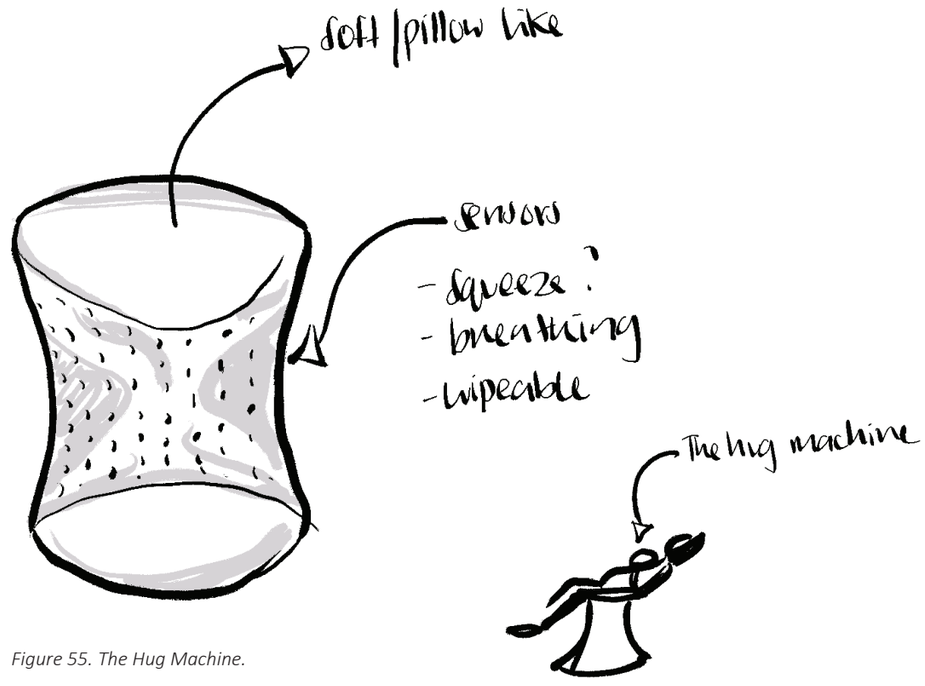


Figure 55. The Hug Machine.

I outlined a potential app that could be paired with the device. That had added features to help patients practice mindfulness and look at their summary of ECG data (figures 56 and 58).

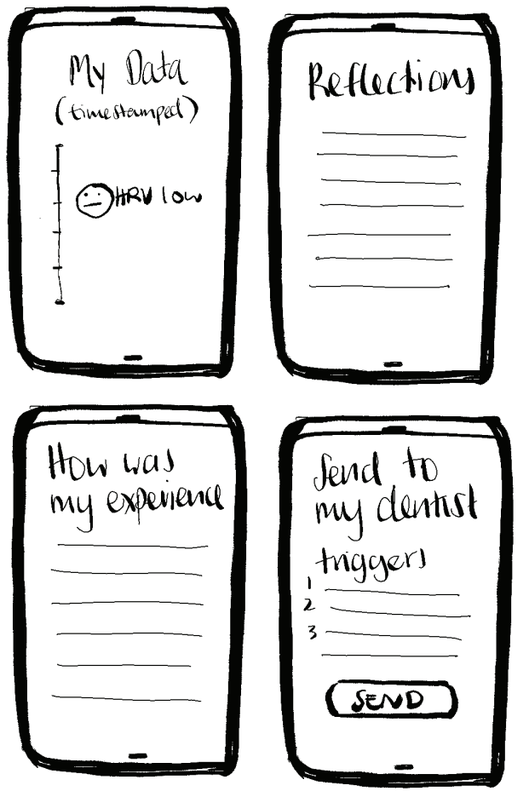


Figure 56. App for providing a summaries of data.

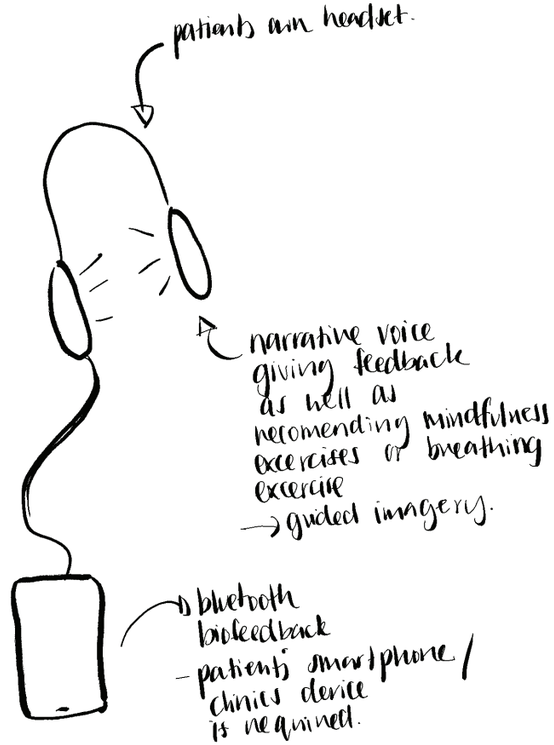


Figure 57. Audio biofeedback.

1. Welcome page.

2. Short Dental Anxiety Questionnaire
To identify a patient's anxiety level upon registering for their first visit, ideally before their appointment, to make the app more responsive to the user's needs.

3. I feel...
A journal entry. (What are my feelings today towards my dental appointment).

4. "Your HRV data will display here."
HRV data will be displayed in real-time for patients to see while waiting in the waiting room. However, this feature will no longer be relevant when they enter the dental chair. Patients are encouraged to listen to the audio and watch their bodies.

5. "How was your experience".
A short questionnaire complements the HRV stress data gathered as a review of their dental experience.

6. "Your Summary."
A graph timestamping showing where their HRV was the lowest indicative of high anxiety. The line drawn marks an average expected HRV at rest.

7 "What can we do to improve your experience next time?"

Often anxious patients, when they've experienced discomfort or high anxiety during treatment, may be unlikely to provide their dentist with feedback because they can avoid confrontation by never seeing them again. This question hopes to break this cycle and help patients navigate a potentially unpleasant or awkward conversation with their dentist.

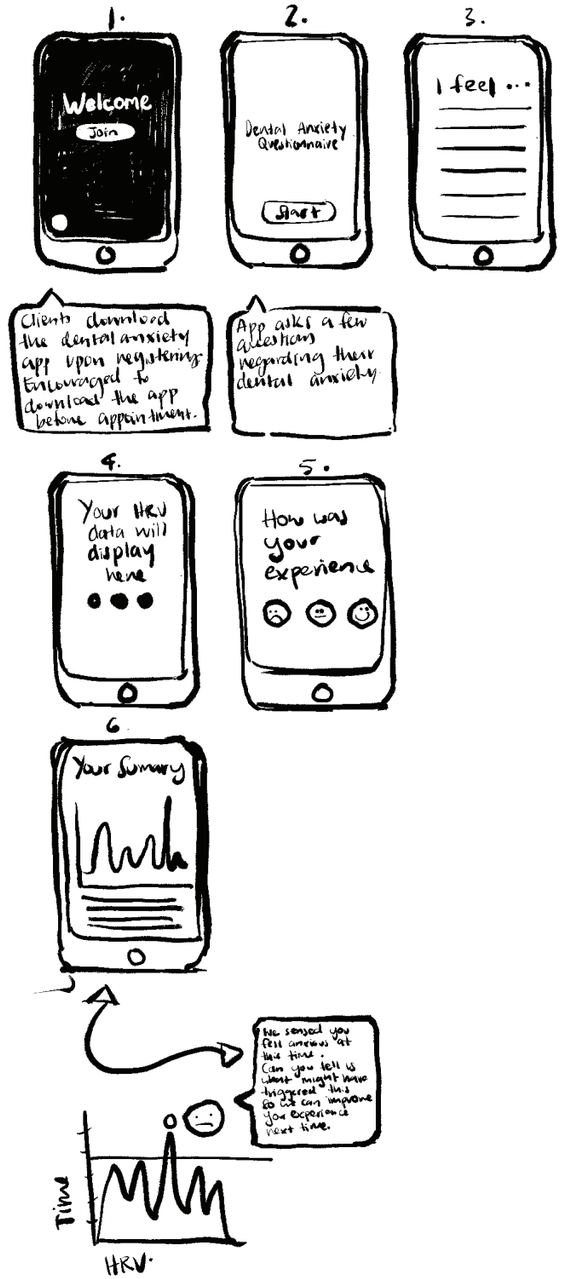


Figure 58. App for providing a summary of data.

System Thinking: Dental Care Services

My reflective practice prompted me to take a step back and revisit the data I had collected during patient interviews. To consider the benefits of biofeedback technology toward improving the overall patient experience.

From my interviews with participants, the waiting room posed a significant challenge for patients. Therefore, I acknowledged that interventions were as essential during this period as during dental procedures. As a means to help patients self-regulate before entering a potentially stressful environment, such as in a dental consultation room where they are likely to be exposed to more disturbing images (e.g. sharp dental instruments) or smells etc. The waiting room also presents an important opportunity for practitioners and other personnel (receptionists, dental assistants, etc.) to engage with patients, evaluate their needs, and assess their level of anxiety. In doing so, prepare a regime to minimise potentially distressing before the patient recieves treatment. As well as, show to patients they care and diminish feelings of shame or embarrassment which often discourage patients from voicing their concerns to their practitioner.

From my interviews with patient participants, patients feared that their practitioner would invalidate their feelings of anxiety if they voiced their concerns about their anxiety. However, Emma felt that a biofeedback device that measured and made visible her level of anxiety to her dentist would help validate her feelings potentially ease her anxiety, knowing her practitioner could understand the extent of her discomfort.

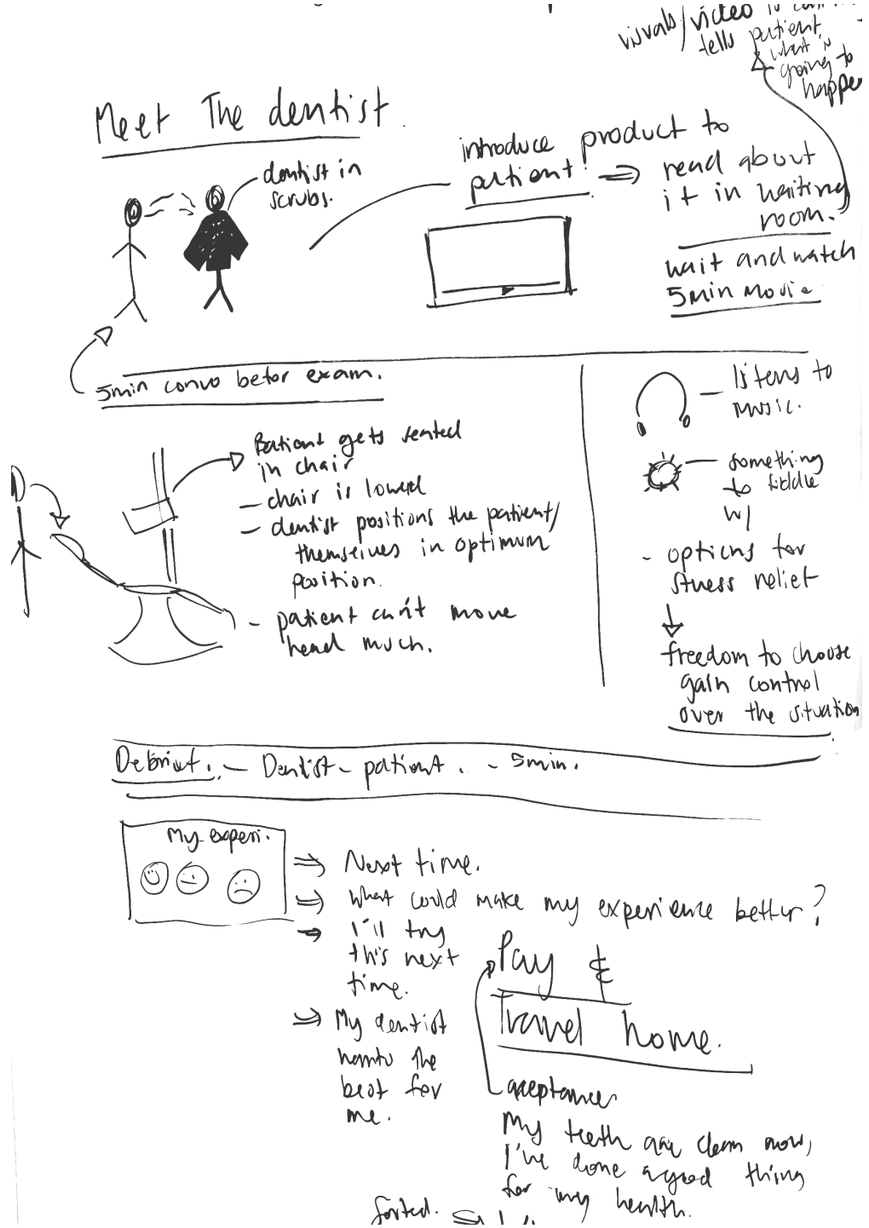


Figure 59. Rough sketch of system.

I unpacked the potential user experience of accessing a dental care service and how my product might enhance the patient experience starting from the waiting room (please refer to system diagram, figure 60 on page 111). I considered how reception staff might interact with patients in the waiting room and introduce the product and app and how staff and practitioners might respond to their patient's data staff. For example, setting aside time for the practitioner to talk to their patient about concerns in a quiet and safe space before entering the dental consultation room.

Example of dialogue between a receptionist staff member and patient:
"Hi, welcome; I see you have registered that you feel a bit nervous about receiving treatment today. As you would have seen on our website, we offer a few options for calming anxiety. Make yourself comfortable and select which options you would like to try today. Your dentist will be with you shortly to discuss any concerns you have and any ways we can improve your experience."

The system I have outlined may require two ECG-weighted devices. One for use in the waiting room and one for dental treatment, as I recognised both areas were equally important. However, I expect only some patients to want or need the weighted blanket. With proper scheduling to avoid back-to-back appointments requiring the weighted sensor device, a clinic may only require one device.

The app aims to prompt patients to talk to their dentist about their feelings, address any worries or concerns they have before treatment, and overcome barriers of shame.
For example, "I'm worried about pain, will there be enough numbing?"
The dentist would listen to their concerns and adjust the treatment plan to minimise potential triggers for the patient. It could also provide additional interventions to help patients manage their anxiety, like mindfulness exercises or guided imagery.

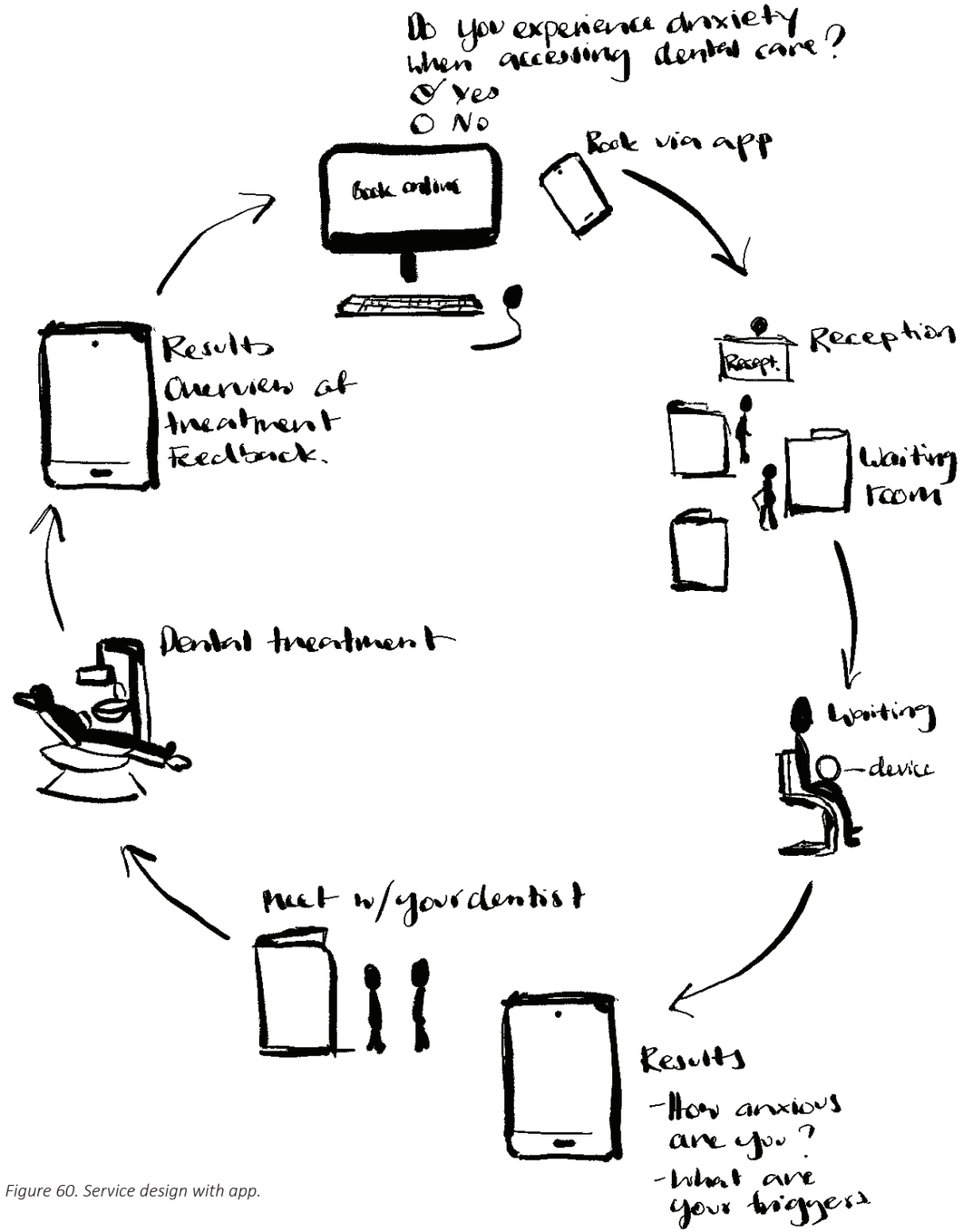


Figure 60. Service design with app.

After some reflection, I decided to simplify the user experience by negating an app interface (see system diagram on page 113 figure 61). Instead, when a patient starts to use the device, the device could sync to reception station computers (or other devices), notifying reception personnel of a patient's level of anxiety. The reception staff would then be supported to speak to the patients and their patient's dental practitioner. The patient's data once collected, could be saved, and stored along with the patient's other vital documents as reference to support care for future appointments.

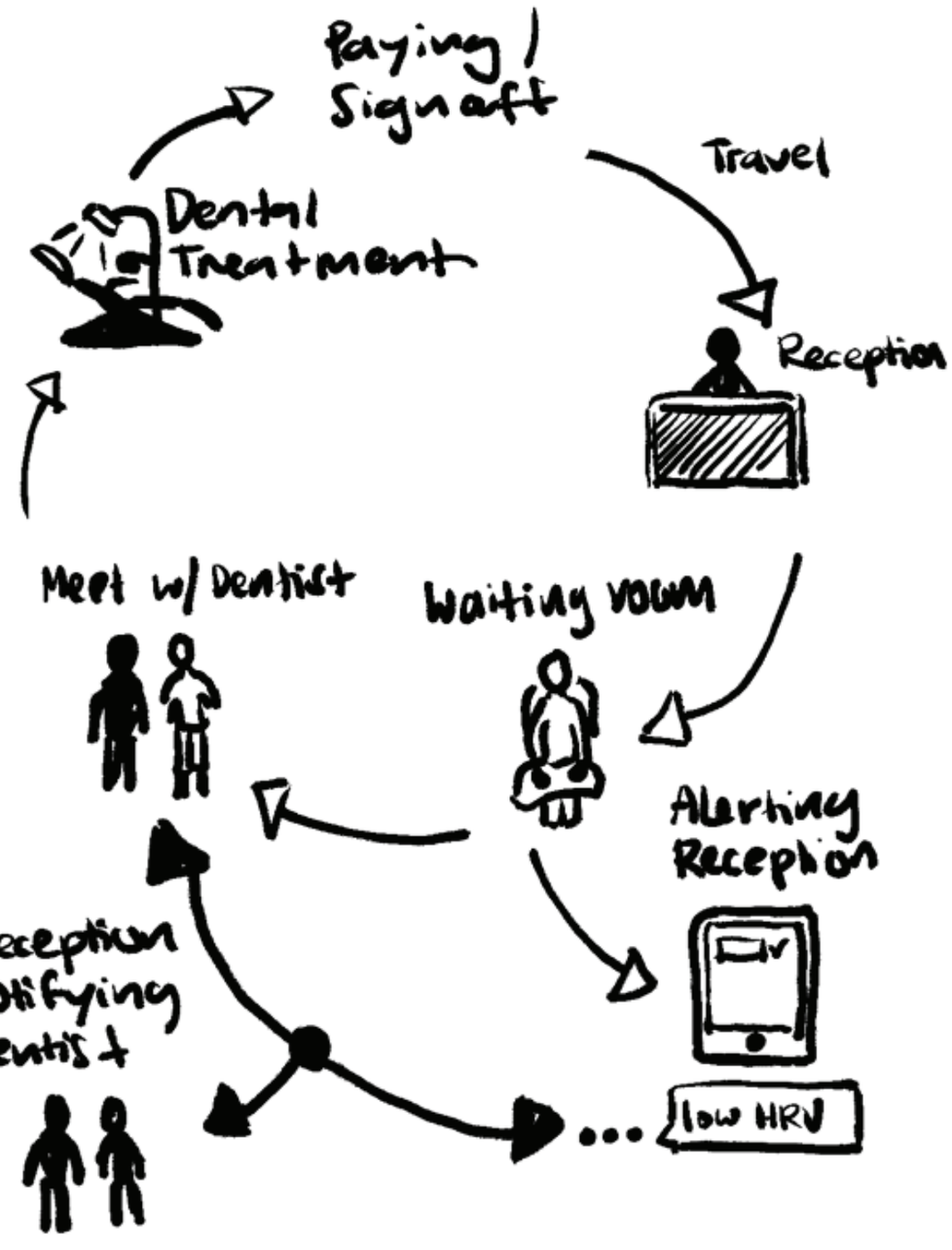
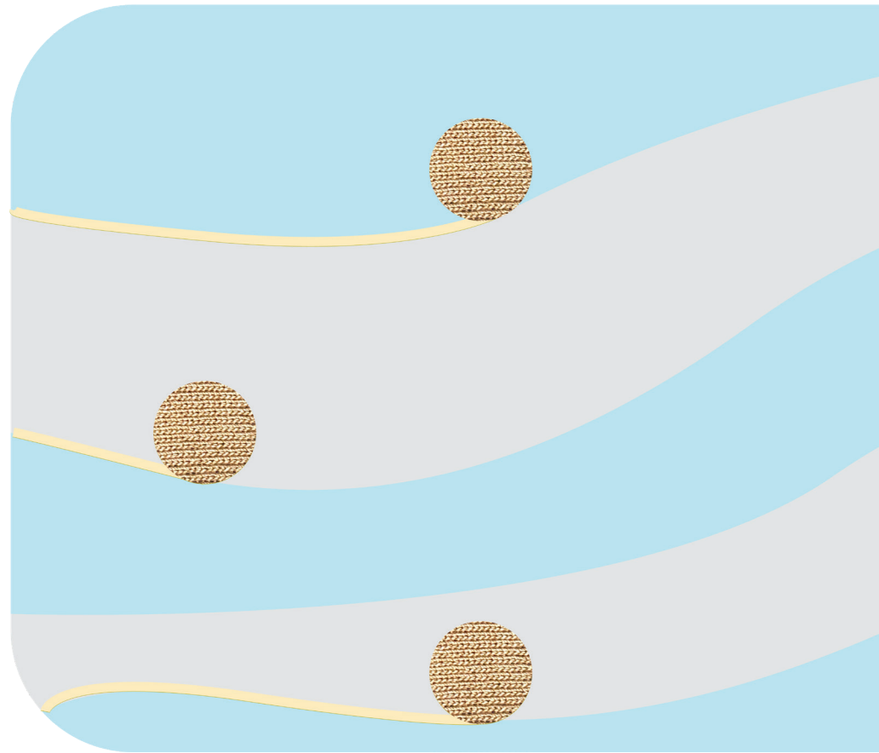


Figure 61. Simplified dental care service design without app.

Develop Chapter

Defining the direction for my project led me to the development stage of my research. In this phase of my research, I explore how users' might interact with the device. I investigate potential materials such as silicone and textiles and how breathing guidance might be applied to help patients' control their breathing.



Wipeable Surfaces for Experimenting with latex

I explored silicone-type materials for the device due to silicones' resistance to harsh cleaning agents such as those required to sterilize dental equipment (e.g. dental chair) (Andrew, Sandra, dental experts). I experimented with latex because of its fast-drying quality and physical resemblance to silicone, making it an ideal material for prototype ideas. Silicones can also be mixed with metals to become electrically conductive, meaning sensor electrodes could be applied to the device using electrically conductive silicone in combination with insulating silicones (Avantor, 2022). The downside to these materials is that they feel cold to the touch and can feel slippery and slimy, mainly when held for long periods due to the material's lack of breathability. I explored different ways of changing the sticky feel of the latex. I applied baby powder to the latex to make it more pleasant to touch, which created a matte surface texture.

I explored shapes and patterns to suggest how the user might interact with the device and to indicate the appropriate location to place hands (where sensor electrodes/conductive silicone would be located).

Figure 62. Latex experiments.

I explored using different textures to provide a sense of tactile distraction for patients. I made a plaster mould to build up layers of latex, creating a thin, flexible material that could be easily stretched and pulled (see figures 63 and 64). I later used this mould to make an air bladder to demonstrate the potential for providing shape-changing tactile biofeedback for guiding users' breathing (see figure 68 on page 121).

Initially, I assumed the use of texture on the surface of the silicone (latex) would create visual and tactile interest and provide a distraction for patients. However, due to the unusual slippery feel of the latex, highly textured surfaces felt uncomfortable and slightly disturbing to touch. Applying texture to the surface also encouraged fidgeting, meaning users may feel disinclined to keep their hands fixed in one spot long enough to provide enough continuous skin-electrode contact required to record accurate ECG readings.

Figure 63. Plaster mould for creating latex skin/bladder.

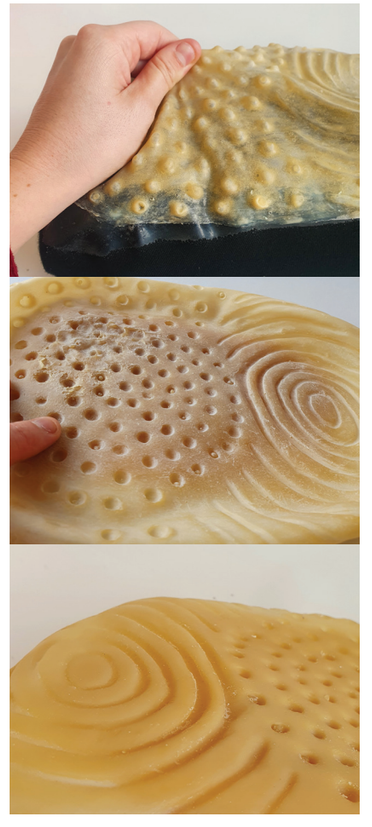


Figure 64. Surface texture on latex bladder experiment.

Deep Pressure and Breathing Guidance for Relaxation

As mentioned, how a person breathes directly effects the CNS (Bordoni, 2018). Mindful, and diaphragmatic breathing exercises have proven to regulate the human stress response (Bordoni, 2018; Hunt, 2021). In dentistry, these techniques are also recognized as useful strategies to reduce anxiety in patients (Appukuttan, 2016; Biggs, 2003; Levi) Exploratory research shows an opportunity to create interactive devices which respond to physiological data like HRV and enhance user experiences (Bin Yu, 2017; Jung, 2021; Ståhl, 2016; Yu, 2021).

Jung (2021) investigated the potential for biofeedback and deep pressure touch (DPT) to influence users' breathing and improve breath awareness. Deep pressure touch was applied using inflatable pads, which inflated and deflated in response to respiration data (inflation supporting inspiration, and deflation, exhalation). The study explored what areas of the body the inflatable pads were most effective at engaging breath awareness. For instance, inflatable pads placed on the lower back or waist areas provided a sense of "support and stability" and encouraged diaphragmatic breathing (e.g., user reported she followed the breathing guidance "without having to think about how I was supposed to breathe."), whereas inflatable pads applied to the upper chest influenced the use of chest muscles in breathing (Jung, 2021, p. 8). When inflatable pads were placed on the shoulders they provided "massage-like qualities" like "someone putting a comforting hand on your shoulder." (Jung, 2021, p. 6) However, when pads were placed on areas such as the legs, they felt strange and disconnected as if they were not supposed to be there.

Therefore, deep pressure touch guidance to support diaphragmatic breathing associated with high HRV would be best applied to the lower back, waist, or stomach (Bordoni, 2018; Jung et al., 2021). Jung (2021) also explored how the pads responded to respiratory data. They explored four different breathing techniques. These included a 5:5 respirate pattern (five second breath in, five second breath out), multiplying the user's breath rate by 1.7 to gradually suggest deeper breaths (increased the duration of time between exhales and inhales), and adaptive feedback which stays at a baseline until breathing becomes rapid and adapts to slowly restore baseline breathing and encourage longer breaths for relaxation (Jung, 2021).

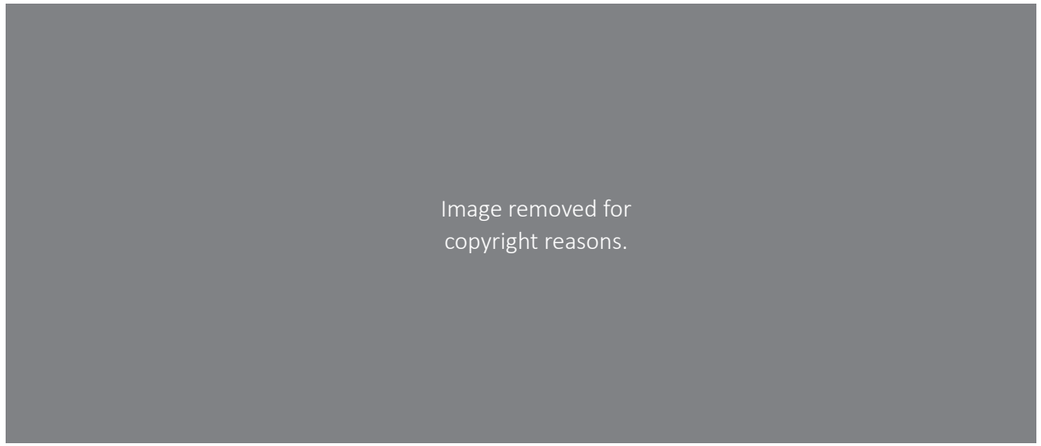


Figure 65. "Modular framework for sensing and actuation control." "Exploring Awareness of Breathing through Deep Touch Pressure" Jung. 2021, p. 5.

Jung (2021) used a respiratory sensor ('RIP') to collect data about user's breathing patterns. The diagram above demonstrates how bodily data can translate to provide tactile ways of engaging with biofeedback (see figure 65). In the case of this research, ECG and RIP sensors would be used to synthesize biofeedback (see figure 66).

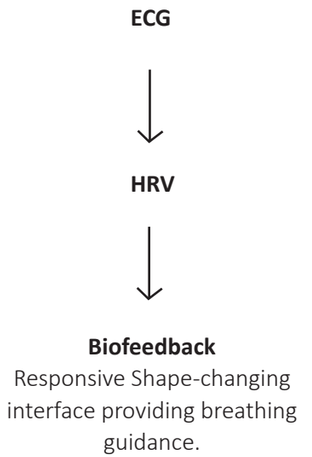


Figure 66. Potential data system for translating ECG into a responsive interface.

Prototyping Breathing Guidance

I conducted a series of experiments using my plaster mould (see figure 64 on page 117) to make a small dome-shaped form for holding air, like the "therapy dog simulation" concept (see figure 53 on page 103). I pasted latex onto a piece of stretchy material to create a seal. Once dried, I glued the edges of the latex/fabric to the form I had cast using my mould.

I blew air into the sealed balloon-like form using a silicone tube and held it to my chest (see figure 70 on page 121). The latex bladder on my body made me feel weightless as it expanded in size—a quality which made it feel alive, like having a small animal resting on your chest.

Inspired by the calming sensory experience of playing with playdough, I selected and arranged a series of images such as round squishy-looking shapes, textured surfaces and soft, radiant lighting (see figure 68). All of which elicited feelings of calm and relaxation.

Figure 67. Mood board for inspiration. Created using online sources.

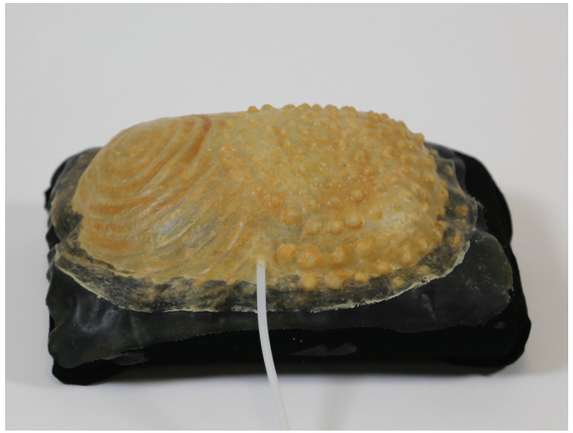


Figure 68. AIr Bladder.

Figure 69. Experiment blowing up the air bladder and holding it closely to my chest.

Table 3. Coding for pumps

Example Coding:

```
#include <AFMotor.h>

AF_DCMotor motor1(1,MOTOR12_64KHZ); // air pumping
AF_DCMotor motor2(2,MOTOR12_64KHZ); // air
vacuuming

void setup() {
motor1.setSpeed(255);
motor1.run (RELEASE);

motor2.setSpeed(255);
motor2.run (RELEASE);
}

void loop() {
motor1.run(FORWARD); // air pump start
delay(12000); // run forward for 10 second
motor1.run(RELEASE); // air pump stop

delay(3000); // 'coast' for 3 second

motor2.run(FORWARD); // air vacuum start
delay (10000); // run forward for 10 second
motor2.run(RELEASE); // air vacuum stop
delay(1000); // 'coast' for 1 second
```


I constructed a coded system consisting of two pumps (vacuum and pump) controlled by Arduino (see table 3 for code and figures 70 and 71 for setup). I programmed the air pumps to inflate and deflate at different intervals to suggest a particular breathing pattern for users. For example, by altering the delay time in my code, I tested well-known breathing techniques like the "box breathing method" (4:4:4) that prompts users to breathe in for four seconds, hold for four seconds, and exhale for four seconds. I also tried combining different breathing techniques in a sequence. For example, immediately after box breathing, I extended the duration of the breaths to 8-4-8. However, this abrupt change was difficult to follow, suggesting that a gradual shift may be more effective at restoring users' breath to a baseline associated with relaxation. For example, Jung (2021) mentioned increasing breath rate using multiplied increments (refer to p. 118).

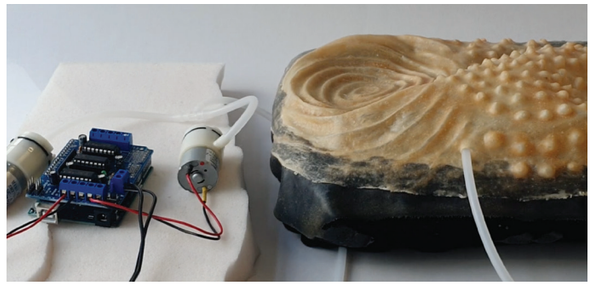


Figure 70. Arduino and motor shield boards connect two mini air pumps in a circuit. Air flows in and out of the latex bladder through silicone tubes controlled by the circuit boards.

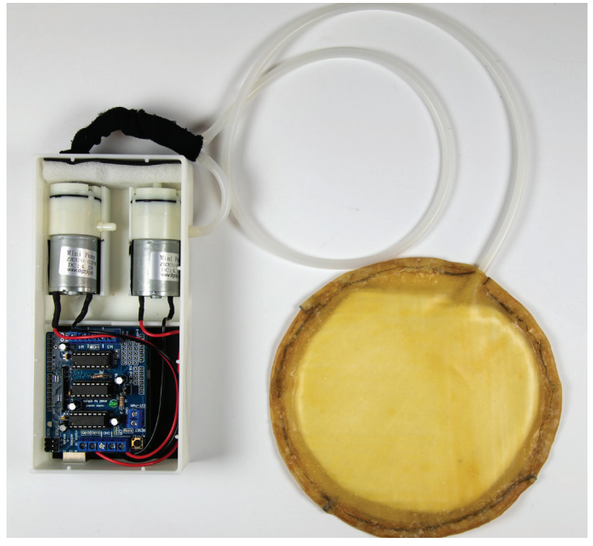


Figure 71. Modified airpump system using air bladder from figure 75.

Figure 72. The cavity/volume inside the bladder was too large and was not filling up with air fast enough. Pressing one hand firmly down on one side made the volume in which air could flow smaller, decreasing the time the bladder took to inflate fully.

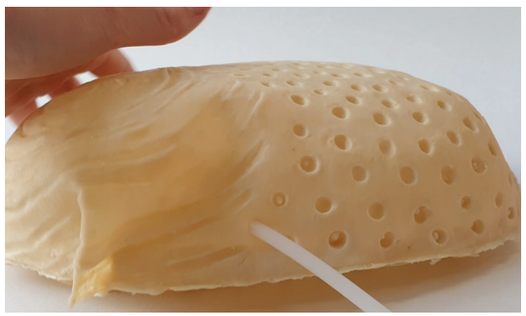


Figure 73. Blowing up the bladder with my own lungs.

I experimented with different ways of dispersing the air inside the bladders. To ensure the change in air pressure causing the bladder to move would be easily felt by users. I developed different bladders with different-sized volumes to find the desired effect to suggest breaths. In comparison, the circular bladder (see figure 75) was small enough for the air pumps to create sufficient air pressure required to inflate/deflate the bladder at preferred intervals. While also fitting comfortably in hand.

Figure 74. Enlarging the surface area of the bladder.

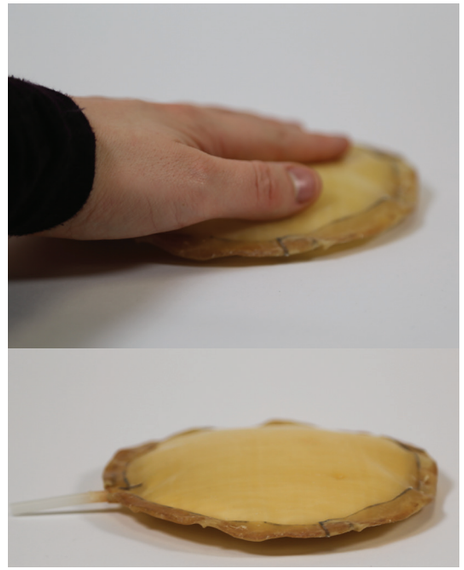


Figure 75. Felt was inserted inside the bladder to reduce the noise emitted from the air pumps. However, the noise still became an issue. This type of bladder was slimmer, meaning it could be inserted into a weighted blanket while minimising bulk.

The problem with these pumps was that they were too noisy. In Jung's (2021) study, participants wore noise-cancelling earphones to dampen the sound of the air pumps. However, using this method in the context of this research is inappropriate because the noise would likely annoy and distract dental practitioners, staff and other patients.

I discovered an alternative to using pumps, shown in figure 76 on page 127, which had a similar effect to the air pumps—a mechanism which moves slowly up and down. The only negative I found was it created more bulk in the blanket. The air bladder lies flat until the chamber fills with air, and electronics can be situated to the side of the blanket to avoid hard edges pressed against the body. In contrast, mechanised breathing guidance requires a motor located on the underside of the moving disc to issue breathing guidance.

Figure 76. Breathing doll simulator.

Integrating Sensor Technology and Exploring Potential Forms

Because of the silicone's weird sticky, and cold feel, I decided not to pursue a pillow made from silicone or any plastic-type material. I wanted patients to feel cosy and secure. Most people associate fluffy blankets with comfort and relaxation; therefore, a textile cover for the weighted blanket might be more familiar and appealing to users. The air bladder in figure 75 on page 125, could be tucked into a blanket cover to provide breathing guidance.

I prototyped a weighted blanket and matching cover with integrated pockets for users could bury their hands and where sensor electrodes could be situated for optimum skin-electrode contact. I constructed the weighted blanket cover from a silk-like fabric found to have calming effects because of its likeliness to human skin (Bertheaux, 2019) (refer to figure 78 on page 129). However, I felt uneasy with my hands in each pocket because it restricted my movement and prompted feelings of entrapment.

Figure 77. Sketches with integrated pockets for situating sensor electrodes for optimum skin-electrode contact.

Figure 78. Prototype with compartments for hands.

Form Development and Hand Placements

I explored different ways to hold the device and the forms which followed. However, a pillow too large and dense became too hard to manage and awkward to hold. I also had to consider that users of all heights, shapes and weights would use the device.

I carefully considered how the design might accommodate patients' different sensory needs. For example, I hugged the cushion close to my chest because the deep pressure it applied helped relieved some muscle tension caused by stress (see figure 79). However, some patients prefer the weighted device placed on their lap, where they can rest their arms and hands. I explored how the cushion might rest on the lap and be clutched to the chest. The device could also include features like heating and audio to provide calm. While testing each form I had created, I analysed areas of the prototype where I felt most inclined to put my hands as suitable places to apply sensor electrodes. I started by prototyping a form similar to the 'Immurelax' device I revealed in my contextual review to understand why they chose this form (immutouch, 2020).

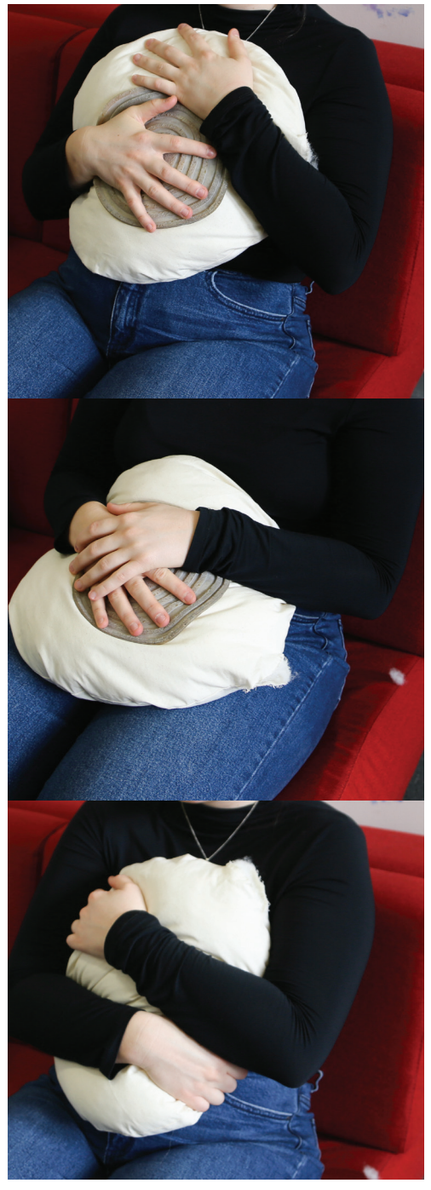


Figure 79. Hugging cushion close to chest.

Figure 80. Testing the size of the log shaped pillow and how it might be gripped in the dental chair.

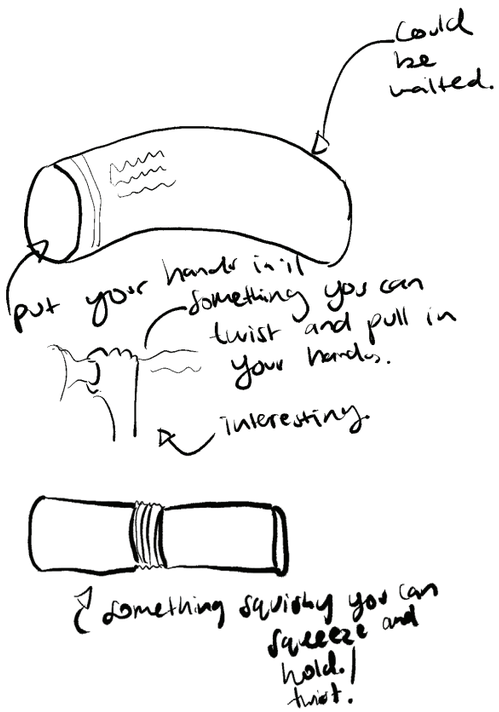


Figure 81. Sketches of cylindrical-shaped form.

I also explored a cylindrical-shaped form, which included a place to squeeze and stretch the device to release tension like a stress ball (see figures 80 and 81). IBTEC engineers assured me that squeezing the device would not interfere with collecting ECG data. However, after testing the shape on myself, it felt too firm and small to hold comfortably. So, I realised something slimmer and more extensive in the surface area might be more effective at applying deep pressure, and there would be no danger of the device rolling off the dental chair mid-procedure.

I thought about carving away areas in the foam to guide users on where to rest their arms to suggest better electrode contact (see figure 82). I thought of this idea after reflecting on my experience accessing dental care (go to page 82). During treatment, I rested my hands on my lap. They did not move throughout the entire duration of the treatment.

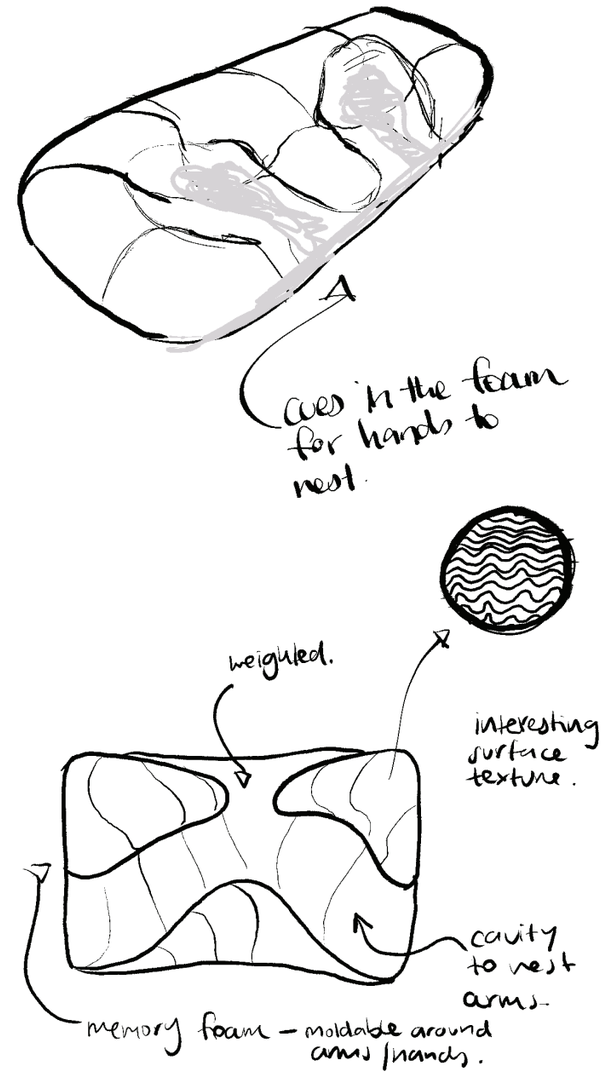


Figure 82. Sketching out ideas reflecting on personal experience in the detnal chair.

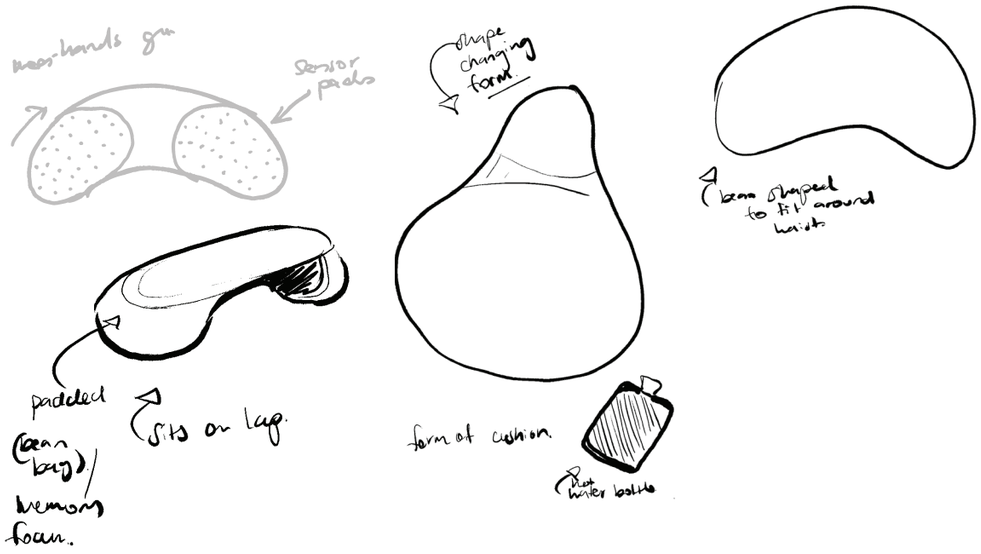


Figure 83. Sketches of organic shape-changing forms for fitting comfortably around the user.

I investigated a bean-shaped form so the cushion could sit comfortably around my hips (see figures 83 and 84). I stuffed the pillow with a bean bag polystyrene filling so that it moulded around my arms once I applied pressure to the form. The material I used to sew the cushion was stretchy, so it readily stretched to accommodate the added pressure. The cushion was comfortable; however, due to the light weight of the polystyrene did not apply deep pressure touch.

Instead, I decided to design a cover for an existing weighted blanket so that if a clinic already has a weighted blanket, I could provide them with a cost-effective option to improve their current weighted blanket. They could also remove the weighted blanket if patients wished only to use the haptic biofeedback breathing guidance that the cushion provided. I also recognised that the design could function not only in dental care environments but in other areas of health, such as mental health or to help those with preoperative anxiety.

Figure 84. Prototype of lap cushion with bean bag filling for shaping around the body's contours.

Refocusing: Textiles as Calming Textures

After investigating the effect of latex (silicone) type materials, I decided to explore what textiles could offer to make the weighted blanket device feel comfortable, visually pleasing and soft. The clinic could own multiple covers for regular washing and sanitization between patients. Therefore, all electrical hardware, such as the ECG monitor, battery and breathing apparatus, needed to detach from the cover easily. The sensor electrodes (conductive textile) would be woven or sewn into the blanket's fabric using conductive yarn, making it washable with the rest. However, more research would be required to determine the effect washing the blanket might have on its lifespan and whether the electrodes would deteriorate after too many washes. I learned from IBTEC engineers that conductive paints and iron-on conductive fabrics often come off in the wash, making them unsuitable alternatives.

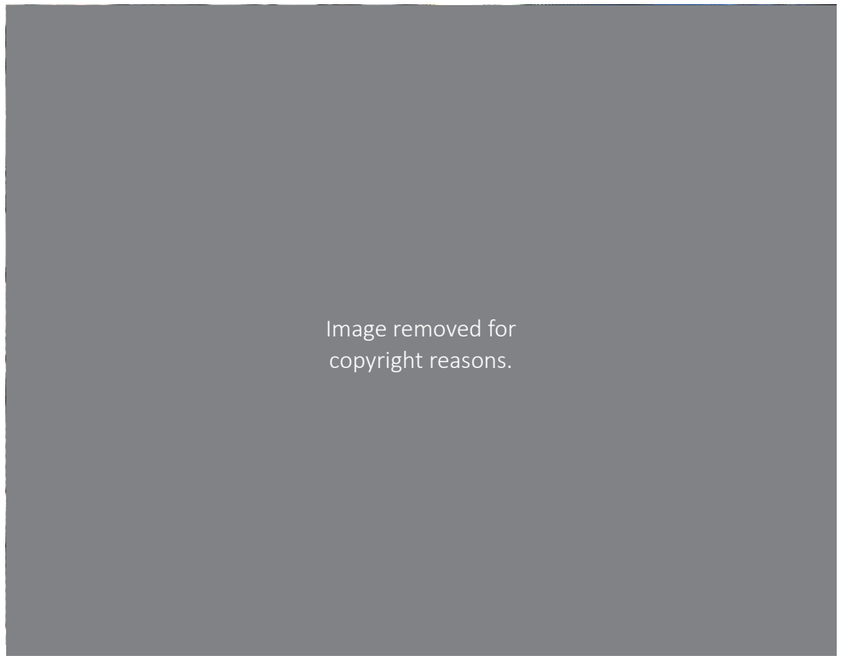


Figure 85. Moodboard: I selected images to inspire me to create different textiles while considering how to integrate an electrical circuit into the design. Images collected from online sources.

Quilting

The quilting sewing process requires two layers of fabric, typically with an interior insulating layer, stitched together using repeated rows of stitching. These rows of stitching create interesting surface texture (refer to the mood board, figure 85 on page 136).

I used this technique by inserting cotton batting between two layers of satin fabric, which I stitched together following lines I had drawn to organize my rows of stitches. I wanted the rows of stitches to act as visual and tactile cues to guide users on where to place their hands for ECG sensing correctly (see figure 86). The fewer layers (two layers approx. 5mm thickness) between the pieces of satin fabric provided less of a contoured surface effect, which could have been more evident and engaging than the experiment with a more significant number of layers of cotton batting (8mm thickness).

Figure 86. Quilting experiments.

Felting

Felting with wool provided a quick way of prototyping to realise my ideas before translating them again using different materials. I created texture by embedding small round felt balls into the felt backing (see figure 87). Although this added an interesting texture, the detail encouraged fidgeting (e.g. stroking or rubbing), actions which would not allow sufficient time to gather an ECG reading. As mentioned, five minutes of continuous skin-electrode contact is required to collect reliable ECG data. However, creating large round raised felted dots like those shown in figure 88, fit comfortably in the palm and acted as tactile cues urging users to place their hands on the sensor electrodes/raised surfaces.

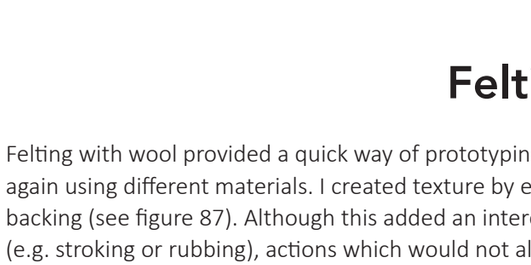


Figure 87. Large felted dots.

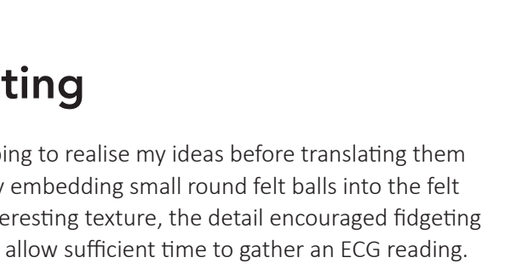


Figure 88. Small tactile felted dots.

Multifunctional Forms

To give patients more options on how the blanket could be used or held, I designed it to fold and become smaller (see figure 89). The blanket could be worn on the lap or folded and placed on the chest or stomach. I also considered how the weight would feel doubled when folded due to a decreased surface area, meaning less dispersion of weight over the body. Moreover, I considered where electrodes might be placed to allow for both positions. I avoided placing electrodes on the fold crease because they would become redundant once the blanket was folded.

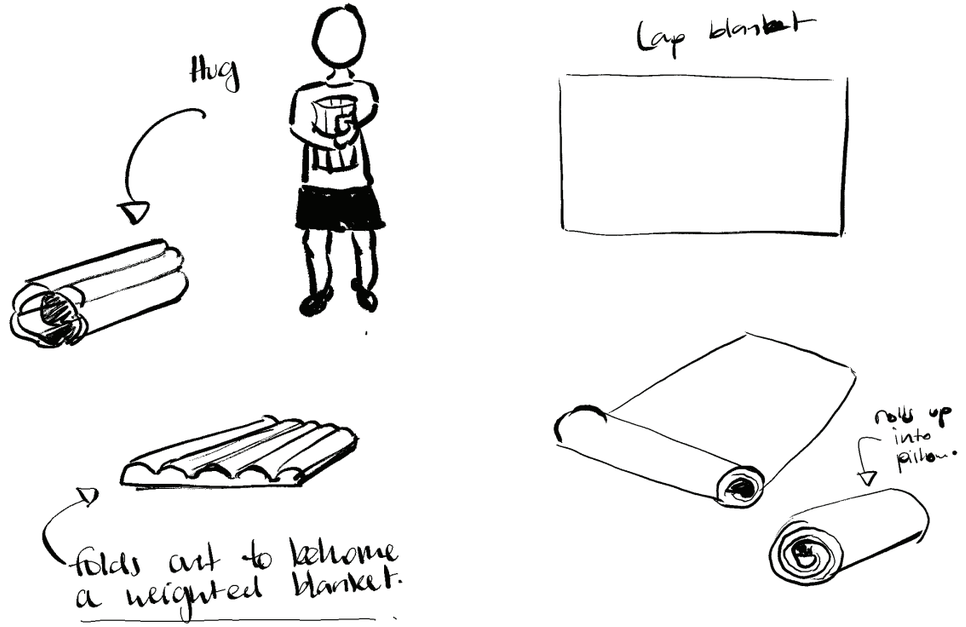


Figure 89. Sketches of concepts related to multifunctional forms.

Arrangement of ECG Electrodes

I experimented with the potential arrangements of sensor electrodes. In order to keep the soft texture of the textile I decided to design smaller eletrodes, but more arrange them in a way that users would naturally grasp them (refer to figure 90).

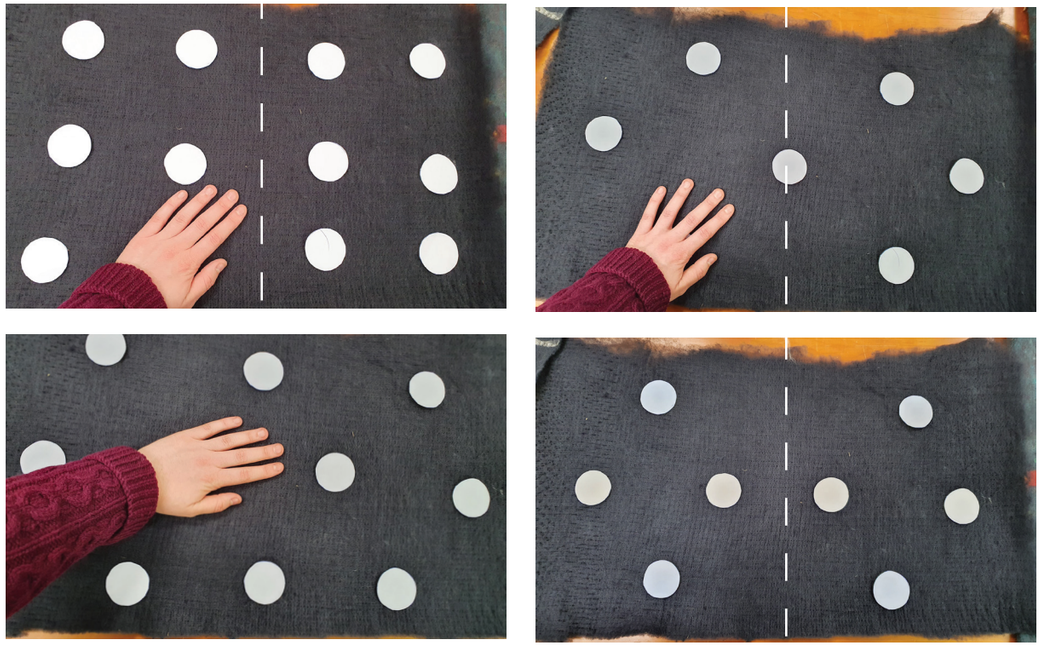


Figure 90. Exploring the arrangement of different electrodes using cutout paper circles representing potential ECG electrodes and moving to create different combinations. The dotted line suggests where the cushion or blanket might be folded in half to be worn on the chest area.

Figure 91.Testing out how the pillow might be held while seated and lying back1

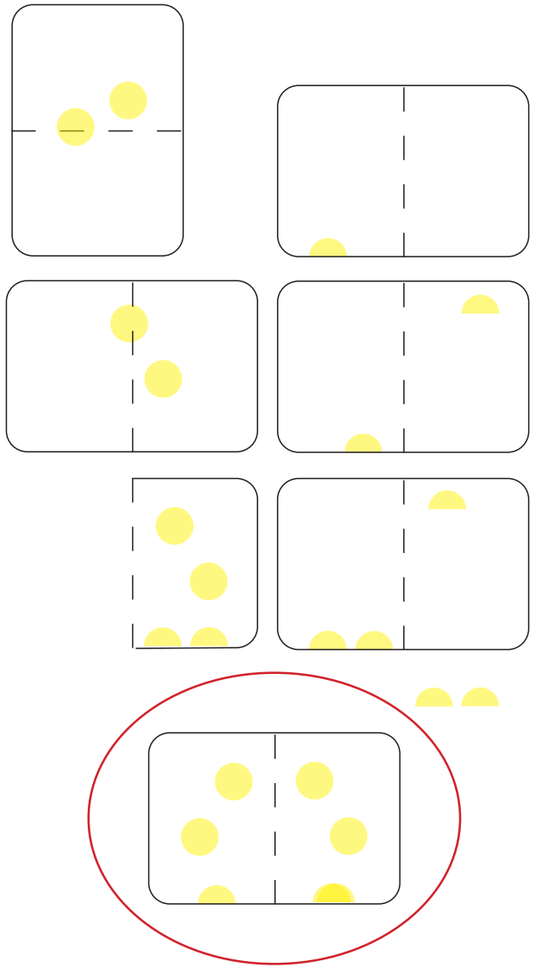


Figure 92. Configuring potential positions for the sensor electrodes.

The cushion in figure 92 was too large and fit uncomfortably around the sides of the body, lacking the hugging effect associated with deep-pressure touch therapy. However, this experiment helped me identify more ways users might hold the device to ensure sensor electrodes were placed correctly to enable skin-electrode contact (refer to figure 92).

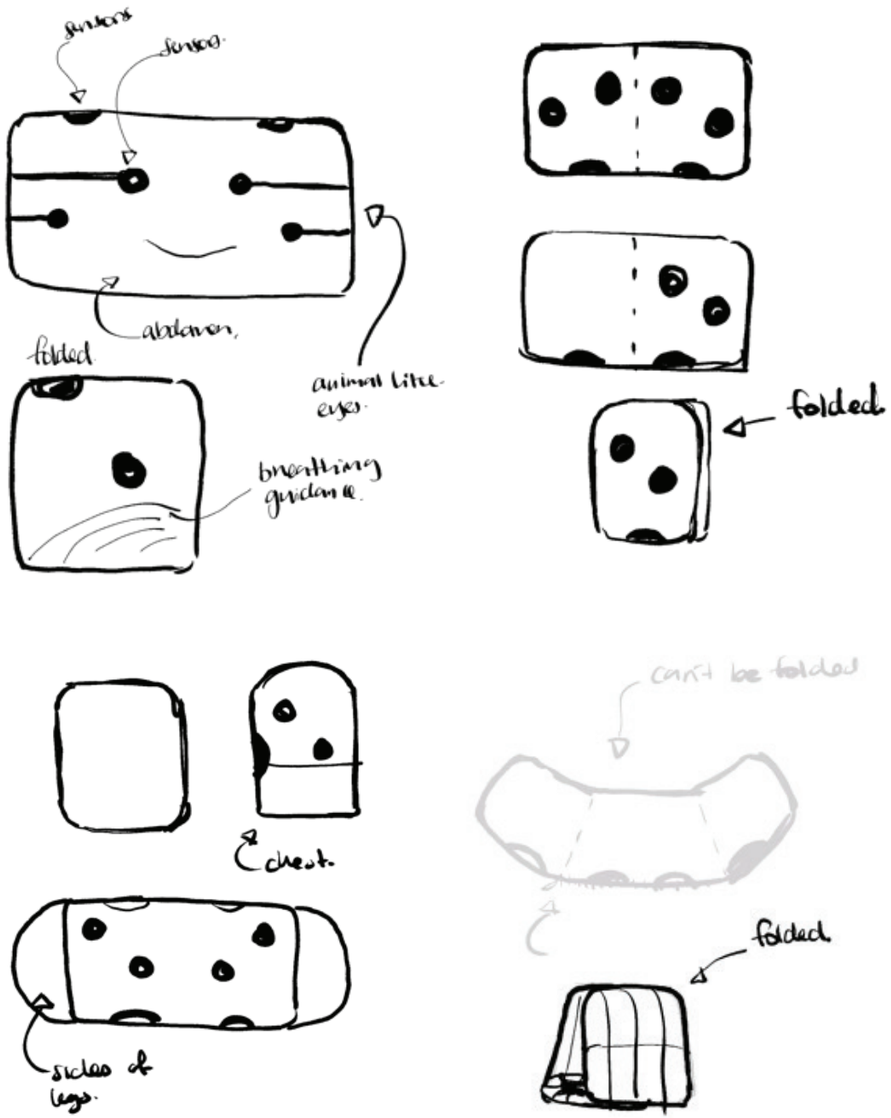


Figure 93. Sketches of concepts accommodating the appropriate arrangement of sensor electrodes to optimise skin-electrode interface.

Figure 94. Prototype with felted conductive wool. Testing out whether the positioning of electrodes is appropriate.

In my follow-up interview with patient participant Emma, she shared he liked the design idea.
"I think I'd hold it on my lap." Patient participant Emma
"If I hold it on my lap, it feels very secure. Feels like somebody's hugging you. Whereas, if I put it on my chest, then it might restrict my breathing a little. Make me feel anxious. But that feels good."
Emma liked the design but also mentioned she would likely use it on her lap.

Figure 95. Developing a visual design and recording hand positions.

Positioning Tactile Breathing Guidance

After deciding on the shape of the blanket shown in figure 93, it was important I carefully considered the appropriate position to place the breathing guidance. I experimented with the air pump system I had developed to test which position was most effective at guiding my breathing naturally. I did this by attaching a long silicone pipe to the air bladder and placing the bladder on different parts of my abdomen. Having the breathing guidance set just under the ribcage, also where the diaphragm is located, made the breathing guidance more natural to follow. In addition, having it placed here meant it sat close to my skin without the bulk of the waistband of my jeans interfering.

After determining the appropriate position of the breathing guidance, I thought it unnecessary for the blanket to require a fold to allow users to clutch it to their chest. The added bulk of the breathing guidance prevents it from folding unless two breathing apparatuses are situated on either side of the blanket away from the fold. Patient Emma also mentioned she would prefer to use the blanket on her lap. To ensure the blanket was long enough, I explored different sizes which might accommodate the breathing guidance and cover the abdomen while seated and lying down (see figure 96). I settled on a simple rectangular shape, based on measurements taken from Sensory Corner's weighted lap blanket (see page 89, figure 44), which I determined would sufficiently cover the abdomen area without add-ons. I intended to model the cover of the weighted blanket from this design to show how the blanket could tailor to existing weighted blankets and sizes.

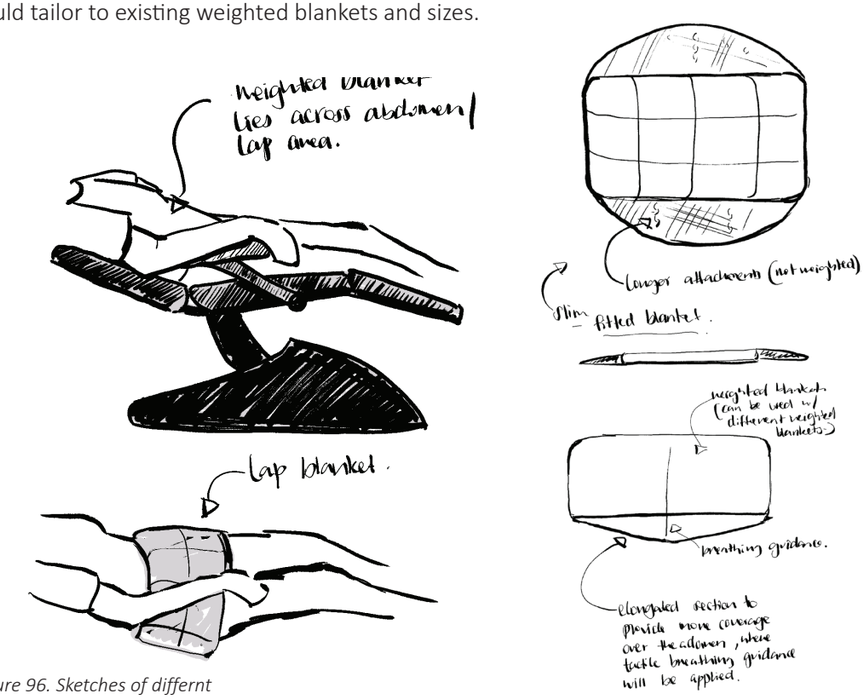


Figure 96. Sketches of differnt

3D Knitting Technology

3D-knitted textiles offer many benefits, such as easy scalability. In this research context, knitted covers could be tailored to different-sized weighted blankets. Meaning healthcare institutions outside of dentistry that would also benefit from the outcome of this research (i.e. mental health, where these blankets are typical) could utilise their current weighted blanket instead of spending unnecessarily. Moreover, the capacity to produce fully functional electrical circuits and provide the flexibility of colours and yarns, visual designs and knit structures, all customisable to different situations or preferences. Knitted e-textiles are also washable.

During a follow-up interview with patient participant Emma, we discussed what sort of feel would be most appropriate for the blanket and comfortable to use. I showed various knitted samples: these samples were made from merino wool or highly breathable cotton to benefit nervous, sweaty hands.

She favoured the merino knit with a tight interlock knit structure, making it devoid of too much texture and extra soft in hand. She commented that patients might be sensitive to texture, so something simple with little texture, for example, something smooth and soft, might be more appropriate than something with too much texture. Too much texture, such as loose knits, would make it less resilient to pulling and stretching. A tight-knit one might be more durable and capable of withstanding regular washing.

Figure 97. Samples on display at the AUT Textile Design Lab on Mount Street, Auckland CBD.

I explored using different knit structures, which gave the wool attractive textural qualities to signal to users where sensor electrodes might be situated (see figure 98). In addition to using different knit structures, foam or other materials, such as felt, could be used as a backing material to raise the surface of the knit structure. So, when patients are in the dental chair and cannot look down to see where their hands are touching, they can feel each sensor electrode. Ensuring they make appropriate contact with sensor electrodes.

Figure 98. Experiments using different knit structures to create texture.

Figure 99. Smooth soft texture using a tight interlock knit stucture, knitted with a merino wool yarn.

3D Knitted Circuit

I programmed a knitted swatch of a sensor electrode using a conductive yarn. With the assistance of a textile lab technician, I combined merino wool with conductive yarn. I did this expecting it to make the sensor electrode softer to touch. This experiment was somewhat successful; it made the knit stretchier, less rigid, and abrasive than the regular knit (using all conductive yarn). When I tested this swatch with engineers from IBTEC, it had a low impedance required for an ECG. Therefore, it successfully gathered ECG despite the combination with the merino yarn.

However, when knitting all eight sensor electrodes to deliver the final design outcome, the merino and conductive yarn intertwined randomly, causing uneven coverage of conductive yarn (see figure 102 on page 151). Thereby, each sensor electrode (section of knitted conductive fibre) would be different and potentially have greater or less skin-electrode contact. Therefore, in the end, I decided to use only conductive yarn to incorporate the sensor electrodes and connect them to the circuit. However, more research could be done on e-textiles and improving the feel of the conductive fibres on the human skin.

Figure 100. Sample with a combination of merino and conductive yarn.

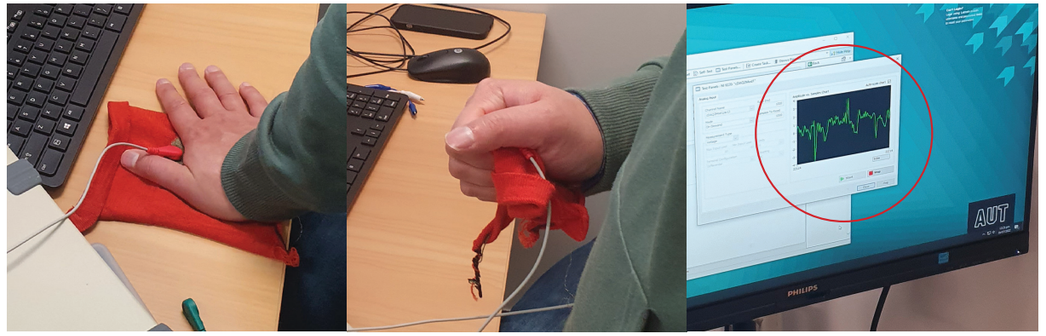


Figure 101. Testing the reliability of the knitted electrode with merino. Results concluded it functioned appropriately.

Figure 102. Combination of merino and conductive yarn knit together.

Temperature Regulation

Some patient participants mentioned using a heated or warm fluffy blanket to help them feel calmer in the dental chair, so I began thinking about ways to regulate the blanket's temperature for optimum comfort. I looked at a couple of options, such as a coiled heat pad or thermally conductive heating fabric, which, hooked up to a power supply, radiates and spreads heat through the entire fabric (Eeonyx, n.d.). I decided to apply this material to foam underneath the knitted cover with sensor electrodes because it would not need to be washed. I also looked at integrating additional conductive patches using 3D-knitting technology to conduct heat throughout the blanket. A low-tech idea was also to design a compartment that stowed an optional extra blanket for added comfort.

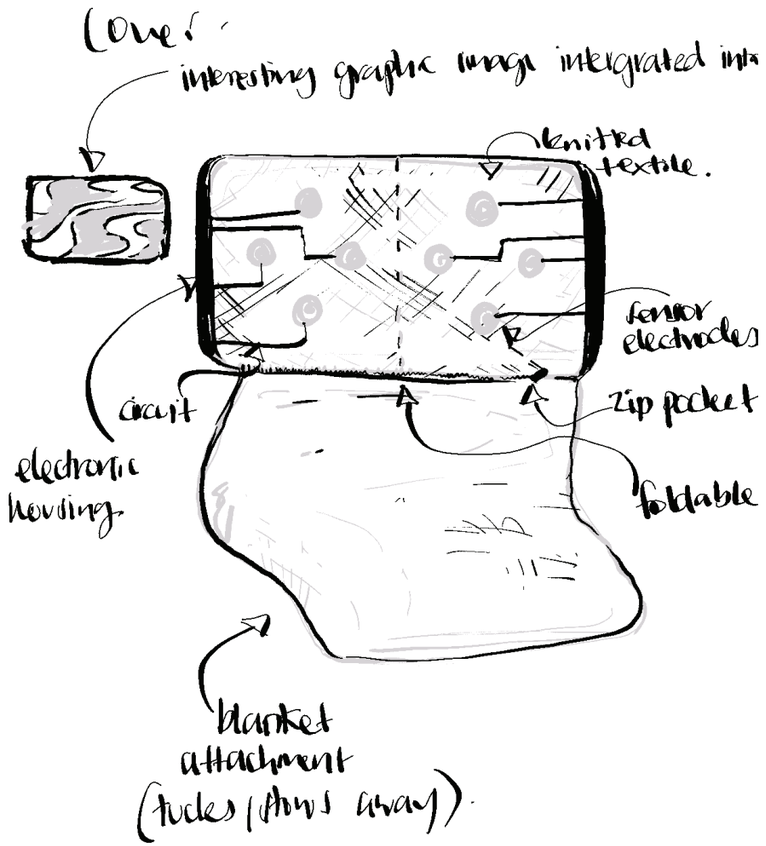


Figure 103. An overview of design features.

Circuitry and Visual Aesthetic

After determining the appropriate arrangement of sensor electrodes, I explored how different visual designs, patterns, and colours might disguise sensor electrodes to make the blanket more appealing to users and less like an ECG monitoring device. I thought this was important to protect patients from shame for being monitored for their dental anxiety. I also explored different-shaped electrodes; however, round electrodes functioned best because the round shape fits better to the palm's contours than a square or triangular-shaped electrode.

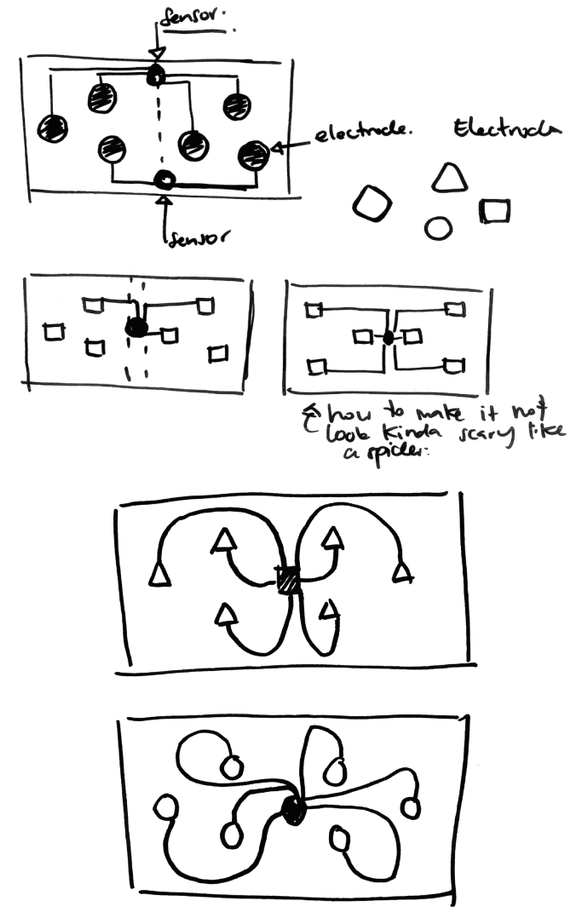


Figure 104. I explored the potential use of different shaped electrodes and how they might be connected in a circuit, while maintaining visual appeal.

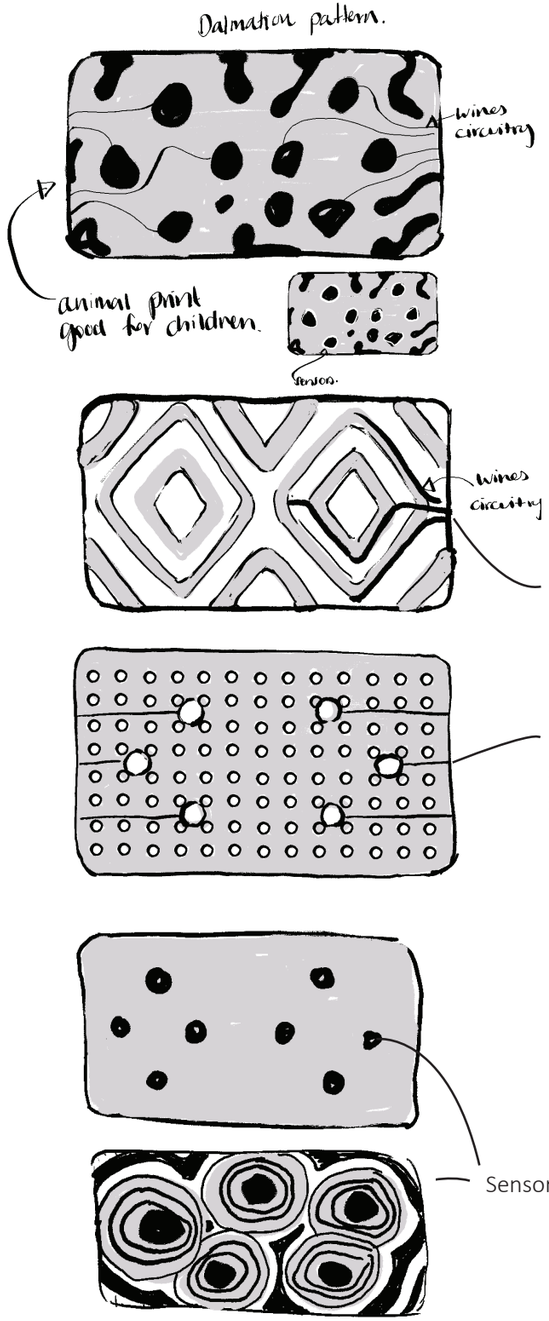


Figure 105. Sketches of possible visual designs for the knitted cover.

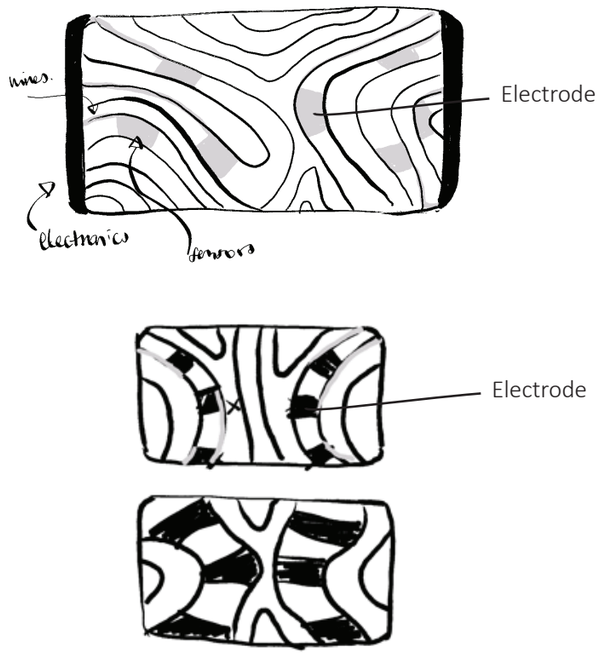
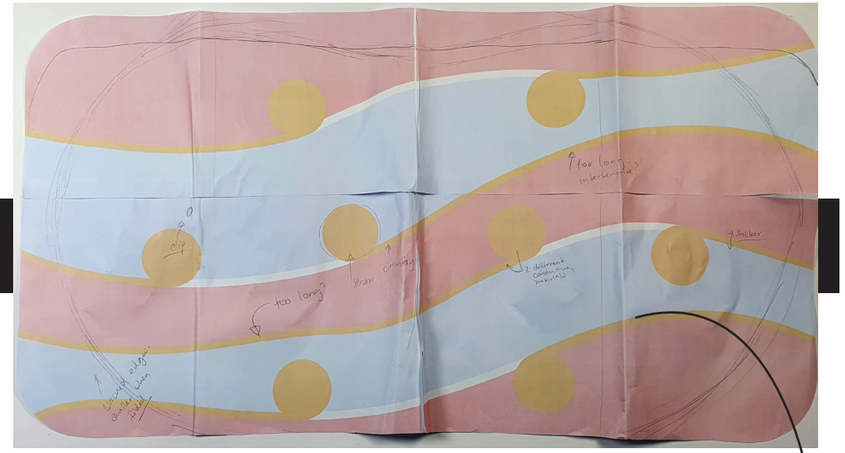


Figure 106. Simplifying the visual cover design.

Figure 107. Testing the scale of the visual design on paper.



ECG monitor and power supply.

Wires needed to be thicker to provide a more reliable ECG reading.

Figure 106. A paper mockup of the design to test its scale. I added two additonal electrodes after testing.

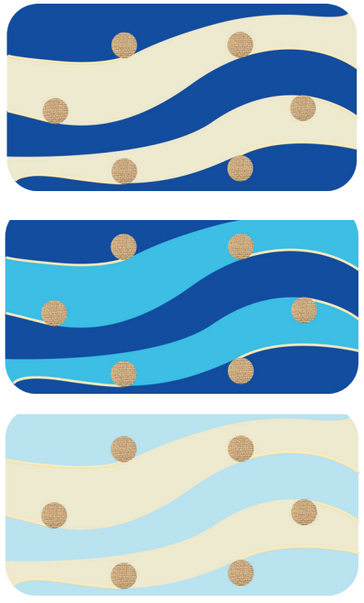


Figure 108. Exploring different colour combinations.

Further discussion with lab technicians revealed an opportunity to use programming to hide the circuit connecting each electrode from the visible exterior. That way, improve the visual design by making it less like e-textiles and more like a regular blanket that users would find familiar. It was a challenge to program the knitting machine to knit in this way. Therefore, more time would be invested into manual programming for full functionality to bring the blanket to manufacture. Integrating the circuit this way also provides greater flexibility due to its two sides. Therefore, endless opportunities for interesting visual compositions.

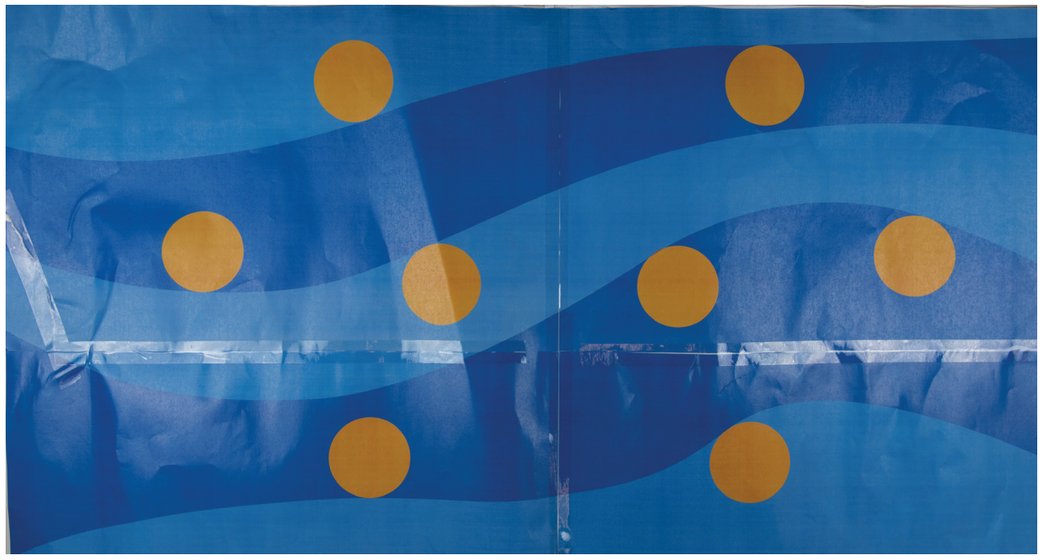


Figure 109. Eliminating the appearance of wires from the design.

My initial plan was to situate the electrical components on either side of the blanket as lifting handles and minimise the bulk of the electronics by splitting them in two. However, from an engineering perspective, this complicated things. Therefore, after receiving feedback on the circuit designs below, I decided to situate the electronics on the left side of the blanket.

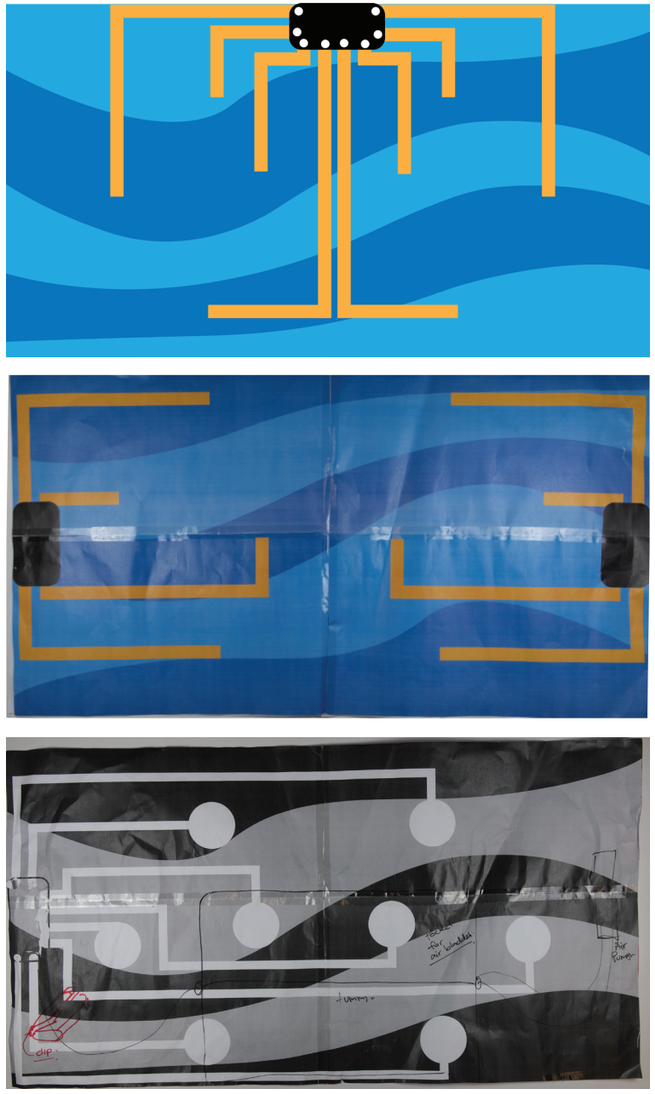


Figure 110. Mapping out the best way to construct the circuit and where the electrical components should be situated.

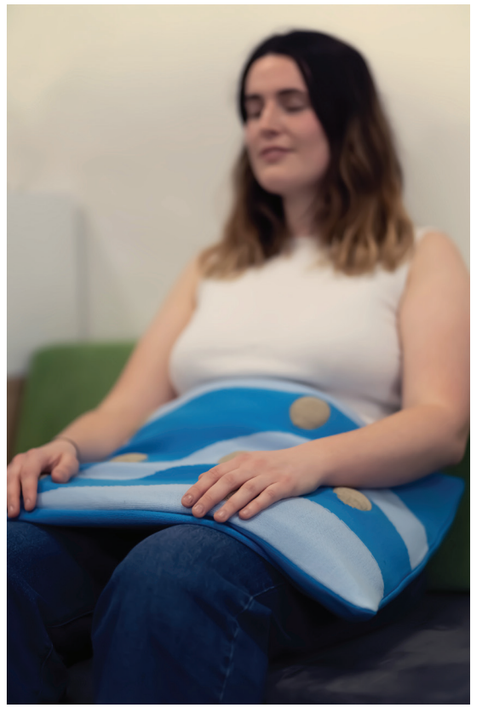
I developed the housing for the electronics, keeping the form slim and long to minimise bulk. Snap fasteners were the most trusted option for ensuring a good connection to complete the circuit. However, more research could be done to investigate better ways to connect the e-textile to the electronics. I feared that the snap fasteners opening and closing would cause the knit to stretch due to the pulling.

Figure 111. Prototyping potential forms for housing the electronic components (i.e. ECG monnitor, circuit board, and power supply).

Deliver

A Cushion to Comfort

An Interactive Sensory Intervention for Dental Anxiety



3D knitted cover made from merino wool and conductive yarn using an interlock knit stucture for rigidity and durability.

Circuit to connect electrodes to ECG sensor.

Connection to sensor electrode on outer facing layer.

Figure 100. Interior circuitry.

Metal snap fasteners for attaching ECG monitoring component, see page 175.

Rubber holder to keep sensor and power supply in place.

Invisible zip and pocket to stow weighted blanket.

Padded interior for stowing weighted blanket and electronics.

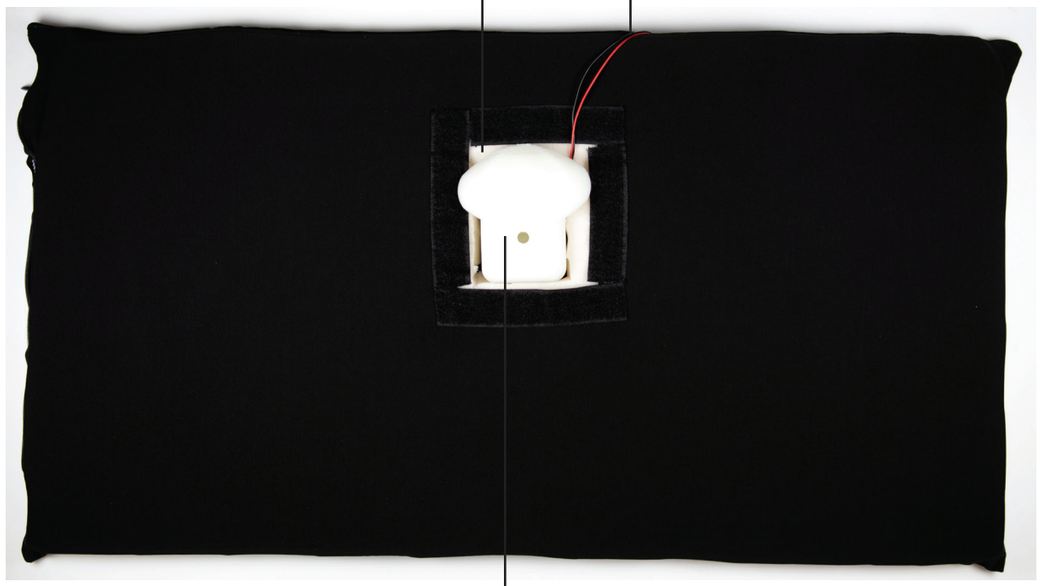
Snap fastener closure for attaching component to the e-textile.

Electronics compartment housing an ECG monitor, wifi for wireless connection and a rechargeable battery.

Weighted lap blanket weighing approximately two kilograms.

2.5 kg weighted blanket, approximately 40 by 75 centimetres.

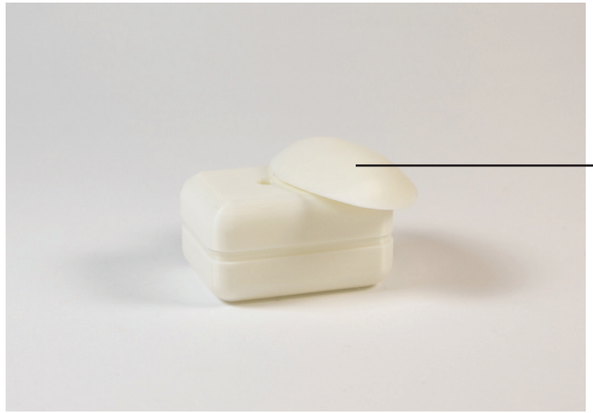
Link to see a video of the device in action:
https://youtu.be/Ot8Ua49pvIA



Memory foam approximately 25mm thick to cushion interior mechanics for issuing breathing guidance.

Connection to ECG monitor and power supply component.

Breathing guidance mechanism situated underneath the blanket directed at the adominal region just below the ribcage where the diaphragm is located.



Modified breathing doll simulator (see page 127 figure 76) by shortening the protruding arm and increasing the surface area of the round domed shape.

Discussion

Research outcomes

I identified five themes from the qualitative data I collected. These included the importance of listening to patients' needs, early identification of dental anxiety, and time pressures' impact on how practitioners interacted with patients. Additionally, how the combination of dental anxiety and dental treatments affected patients' breathing and the potential effectiveness of distraction techniques, calming visuals and activation of proprioceptive senses through deep pressure, heat and soft textiles could help reduce anxiety in patients.

I consistently referred to existing literature during my research to validate the insights I gained from participant interviews—for example, the implementation of dental anxiety questionnaires for measuring patients' levels of dental anxiety. Ogawa (2022) found practitioners overestimated how well they could identify anxious patients. The study revealed dental practitioners rarely implemented dental anxiety questionnaires in practice. In addition, they were often only used after practitioners received complaints about anxiety directly from patients (Ogawa, 2022). The ill use of these dental anxiety questionnaires echoed my interview with dental expert Andrew. He acknowledged that a patient's anxiety is not always apparent and that practitioners often discover too late to offer patients options to help them manage their anxiety. My research argues that if practitioners are informed of their patient's level of anxiety pre-treatment, they might have a greater opportunity to discuss with patients what heightens their anxiety and make accommodations during treatment to minimise these triggers.

I identified time as a significant barrier that dental experts said they faced during practice which could potentially correlate with patients' feelings of not being listened to. These time pressures impact how dental practitioners build rapport, actively listen to patients and take time to understand their needs and identify if they are feeling anxious. Therefore, biofeedback technology has the potential to provide practitioners with better and more time-efficient ways of monitoring their patient's anxiety and, in turn, facilitate patients to feel calmer during treatments.

Dental experts shared their approaches to help patients manage their anxiety, which they had adapted into their practice over years of experience. Common strategies were distraction techniques to pull patients' attention from the procedure and stay focused on a particular task. Examples are a dental assistant offering patients a hand to squeeze or tapping them on the shoulder while administering anaesthesia to distract them from the feel of the needle. Moreover, using overhead visuals allows patients to find a particular item in the picture. Dental therapist and hygienist Lauren, who specialises in treating special needs clients, mentioned she also uses squeezy balls and calming essential oils to help calm her patients. When she knows of a patient's anxiety, she will greet them inside the waiting room without her dental gear and hide dental instruments from sight as her patient enters the dental consultation room.

In doing so, this is an example of what measures can be taken to reduce anxiety in patients pre-treatment if the practitioner knows the extent of their patient's dental anxiety in advance.

Furthermore, I found difficulty breathing was a key factor causing heightened anxiety in patients. Patients often expressed concerns about swallowing, having water in the mouth, hyperventilation, and problems adapting to breathing through the nose instead of the mouth. Dental practitioners acknowledged breathing techniques as valuable strategies to help patients manage their breathing, which led me to develop a product that would respond to a patient's anxiety by slowly suggesting a slower breath rate to a baseline associated with calm. Furthermore, from an extensive literature review, I recognised an opportunity to utilise weighted blankets in dental care environments and combine them with ECG monitoring to make a patient's anxiety visible. A sensory intervention to reduce patients in the waiting room and during dental procedures.

Limitations

This research explored the potential for sensor technologies to help alleviate dental anxiety in patients. In this, it is important to acknowledge that ongoing research is required to validate the use of HRV as an indicator of anxiety and emotional distress. As such, further technological development is required to test and validate the functionality of “A Cushion to Comfort”.

Covid-19

This research took part just before the rise of the Covid-19 Delta variant, which resulted in the 2021 Lockdown and four months of enforced restrictions by the New Zealand government. The pandemic affected my research in a few ways, including the participant recruitment, as well as structure of participant interviews. Due to these restrictions, most participant interviews were conducted online via Zoom. Navigating how I could interact with participants in meaningful ways was challenging. Meeting participants in person may have resulted in participants gaining a deeper understanding of my project (e.g., by them being able to engage with physical artefacts) and may have resulted in different insights and potential solutions to improve dental care services. Before these lockdowns, I outlined a study plan to structure the interviews with participants (see appendix C through to appendix F on pages 194-205). In this plan, I had intended to collaborate with trainee dental therapists in non-invasive, non-medically active roleplay prompted by a series of potential user scenarios and semi-structured interview questions. In these I would have been walked through standard dental treatment procedures on-site at a healthcare institution to better understand the process of receiving treatment. However, the facility was closed during the lockdown, and trainee dental therapists completed their learning online for the rest of the semester. The associated fatigue and burnout after months of online study may have made trainee dental therapists less willing to participate in my study due to prior stressors and commitments. Being able to engage more meaningfully with these potential participants would likely have provided better insights into both patient and practitioner experiences.

Moreover, due to the uncertainty and anxiety caused by the covid-19 disruptions, it was not possible to follow up with all participants to gain additional feedback on the direction and outcome of my research. I was able to conduct follow-up interviews with one patient participant and one dental expert. Following up with more participants may have provided more robust feedback with respite to patients' and clinician needs. In addition, of the six patient participants I interviewed in total, all were female. This may have resulted in gender bias in my research.

Testing and Validation: The Next Steps

The following steps of this project would be to follow up with patients and experts to hear feedback about my design outcome. Next, respond to the feedback and work more closely with the engineers at IBTEC to work towards a fully functional prototype, which could be applied in research and validated for its presumed effectiveness in reducing patient anxiety in the dental chair or pre-treatment.

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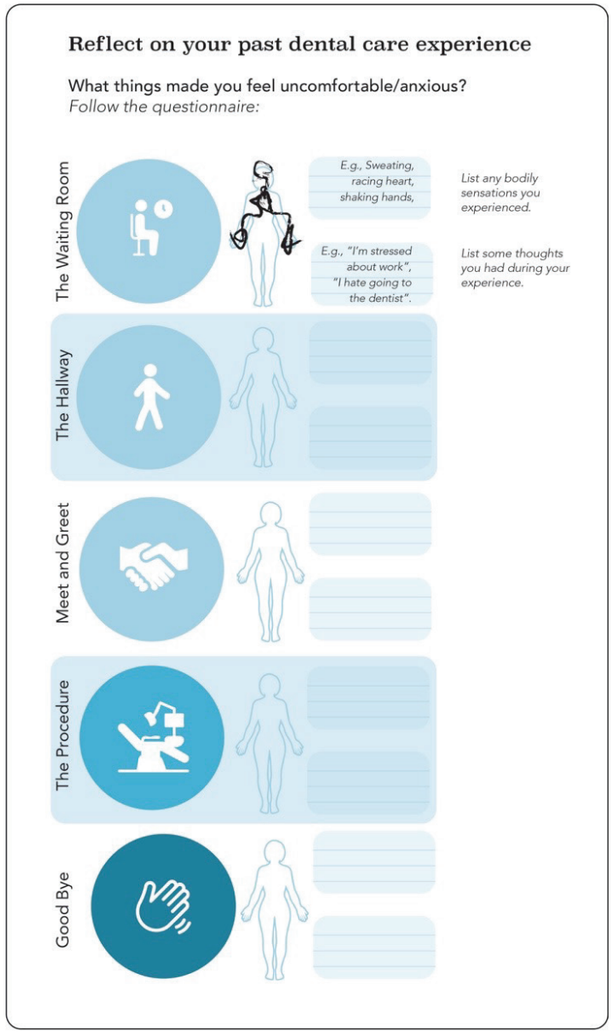
Appendices

Appendix A
Physical visual prompt intended for use in patient participant interviews:

I had intended to give patients a physical copy of a map to complete on their own before commencing the interview. This aim was to give them privacy and a moment to reflect on their previous dental care experience. I had thought of not collecting these during the interview and treating these maps as a way of jumpstarting a conversation and breaking the ice, not pressuring participants to complete it in its entirety.



Appendix B
Ethics Approval:

Auckland University of Technology Ethics Committee (AUTEC)

Auckland University of Technology
D-88, Private Bag 92006, Auckland 1142, NZ
T: +64 9 921 9999 ext. 8316
E: ethics@aut.ac.nz
www.aut.ac.nz/researchethics

6 September 2021

Stephen Reay
Faculty of Design and Creative Technologies

Dear Stephen

Re Ethics Application: **21/285 "Open Wide" Sensory and Technological Interventions for Managing Dental Anxiety**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 6 September 2024.

Standard Conditions of Approval

1. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC in this application.
2. A progress report is due annually on the anniversary of the approval date, using the EA2 form.
3. A final report is due at the expiration of the approval period, or, upon completion of project, using the EA3 form.
4. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form.
5. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
6. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.
7. It is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard and that all the dates on the documents are updated.
8. AUTEC grants ethical approval only. You are responsible for obtaining management approval for access for your research from any institution or organisation at which your research is being conducted and you need to meet all ethical, legal, public health, and locality obligations or requirements for the jurisdictions in which the research is being undertaken.

Please quote the application number and title on all future correspondence related to this project.

For any enquiries please contact ethics@aut.ac.nz. The forms mentioned above are available online through http://www.aut.ac.nz/research/researchethics

(This is a computer-generated letter for which no signature is required)

The AUTEC Secretariat
Auckland University of Technology Ethics Committee

Cc: phy6692@autuni.ac.nz; Daniel Sutton; charlottedickson93@gmail.com

Appendix C
1.1 Research Protocol: Expert Interviews

Research Objectives and Purpose
Interviewing experts will help the researcher gain information, which might not be accessible from literature about how they experience and support dentally anxious patients

Participants
- Dentists, oral hygienists, and dental therapists
- Psychologists and occupational therapists.
- Designers who specialise in designing sensory objects/sensor wearables etc.

Duration
Each interview session will last approximately 30-45 minutes.

Location
Interviews will occur in the expert's private workplace when convenient to them or via a zoom video call.

Recruitment

1. The experts will be primarily contacted through [redacted] or from other areas of AUT but may also be experts from outside of AUT.

Experts will be identified from information available in the public domain and supervisors' and advisors' professional networks. The researcher will invite the potential expert participant to an expert interview via email with the attached participant information sheet and consent form. The potential participants will be given two weeks before a follow-up email is sent as a reminder.

Example of email:

Kia Ora,

I hope you are well.

I am contacting you to invite you to participate in my Master of Design Research at Auckland University of Technology.

I am exploring ways to implement sensory-based methods and biofeedback for helping to alleviate dental anxiety.

I am partnered with the Institute of Biomedical Engineering on this project, which has developed new sensor technology that can potentially be used to measure patient stress via heart rate variability sensors. We are interested in how these might be used to support dentally anxious patients to manage their anxiety when undertaking dental treatment.

I am interested in hearing your expert thoughts via a short interview. Please see the attached participant information sheet below for more information.

If you are interested, please send a reply, and we can organise a date for a zoom call or meet in person.

Thank you for your consideration

Kind Regards,

Sarah
Master of Design,
Good Health Design, AUT.

Consent
Signatures to give consent will be collected digitally and sent via email or given verbally via zoom video call before the interview commences. Participants may also consent to be contacted for an optional follow-up session. These sessions will provide an opportunity for experts to give feedback on designed concepts. The researcher will show visual displays and mock-up prototypes to participants.

What will happen?

2. Interview participants will be asked a series of 5-10 semi-structured open-ended questions.

Indicative questions include:
- How often do you experience anxious patients?
- What do they do/how do they show their anxiety?
- How do you know they are anxious?
- How do anxious patients interrupt how you perform procedures?"
- Have you tried or have experience using sensory (or other methods) methods to help them manage their anxiety?
- If so, what works well?
- From your experience, what other methods or approaches for reducing dental anxiety would be most appropriate for me to explore?"

Interviews may also involve a visual show of mock-up prototypes, cultural probes to encourage discussion, diagrams, and sketches to communicate ideas.

Collection of data
The researcher will record audio as well as take notes. Other materials such as sketches or visual diagrams will be scanned and used in the exegesis. Experts have the option of taking original copies home.

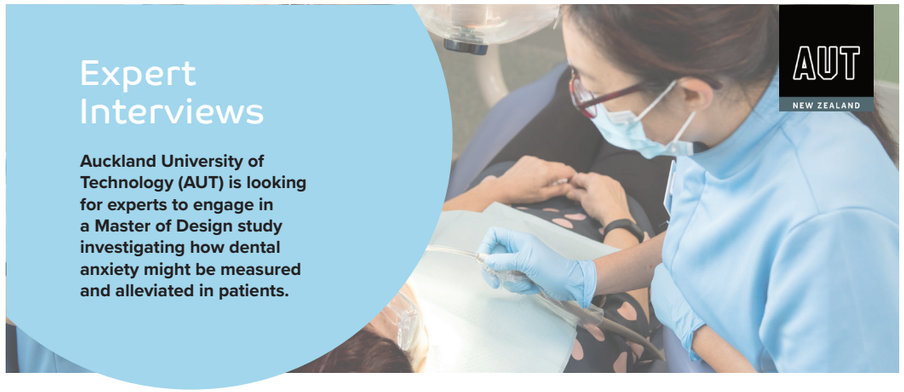
Analysis
The interviews will be transcribed using a collection of audio recordings and notes. The researcher will use thematic analysis to reflect on data gathered from the interviews and support design outcomes.

Participant Protection
Participants will be kept anonymous in any documentation of the data add as above except the researcher and supervisors. Participants can opt out of participating in the research project before analysing the data without being coerced or disadvantaged in any way. The published exegesis and final design outcome will be embargoed, so they will not be shared with the participant.

Storage of Data
The audio recordings, notes, digitally scanned drawings, or other materials collected from the interviews will be stored on an external hard drive and secured in a lockable cabinet along with physical copies inside the Design for Health and Wellbeing Lab at AUT City campus (WE302) organised by the project's supervisor for six years.

Consent forms will be secured in a lockable cabinet in primary supervisor Steve Reay's office for six years.

Summary of Research
The published exegesis and final design outcome will be embargoed, so they will not be shared with the participant. However, a research summary/abstract and snapshots of the design process and key findings from the interviews will be shared with participants until the embargo is lifted and full access to the thesis is granted.



Hi, my name is Sarah.

I am the researcher and industrial designer, behind this project. I am investigating how biofeedback technology and sensory-based techniques can help manage dental anxiety in patients.

What is the purpose?

The purpose of the interview is to learn from your experience as a professional in any of the fields listed, as well as give feedback on designed concepts.

Seeking Experts:

- Dental care professionals
- Psychologists
- Occupational therapists.
- Designers
- Bioengineers

How do I agree to participate in this research?

Your participation in this research is voluntary (your choice), and whether you choose to participate will neither advantage nor disadvantage you.

Before meeting for an interview with me, please sign a consent and release form, which means you have consented to participate in my research. However, you can still withdraw from the study at any time. If you do, I will erase all data from our interview.

What will happen in this research?

I will ask you a few questions regarding your expertise.

I may also show you some drawings or prototypes of ideas for you to give feedback.

Location:

Interviews may take place in person inside a public space such as a café at a convenient location to you or inside your own private office.

You will be required to show proof of a current Covid-19 vaccination passport if you wish to meet for an in-person interview.

Zoom video call

You can also participate via video call (Zoom) or phone call. Please this will not require a vaccination passport.

Duration:

Approximately 45 mins - hour.

We can schedule a time via email which best suits you.

Follow-up Interview

You may participate in a follow-up interview likely to occur between 2-4 months after your initial interview with me. At this stage, I will have more developed concepts to show and have had time to respond to your initial feedback.

What are the discomforts and risks?

Some of my questions might not be directly related to your expertise. You may feel uneasy answering some questions.

How will these discomforts and risks be alleviated?

I will try to make you feel as comfortable as possible. I want you to leave feeling you have made a meaningful contribution to the project. If you are uncomfortable answering some questions, I will move on to another, no questions asked.

Turn the page over

What are the benefits?

Your involvement will help me develop a design outcome required to complete my Master of Design qualification. AUT's Institute of Biomedical Technologies (IBTec) may implement the design in the future. The published study may also encourage further study in your area of expertise.

How will my privacy be protected?

You will be kept anonymous in any data documentation and will not be known to anyone except myself and my supervisors. The data I collect will be stored in a safe and secure place accessible only to myself and my supervisors. You also can take physical material such as drawings or notes home. However, I will digitally scan all material after the interview and use them to develop my design ideas.

I will audio record the interview to transcribe and write down any notes I may have missed later. However, the raw audio recording will not be published, and data that might identify you will be removed during analysis to protect your identity.

What are the costs of participating in this research?

The interview only requires your time and effort.

What opportunity do I have to consider this invitation?

You have two weeks to communicate interest in participating. After two weeks, you will receive a follow-up email as a reminder. If I do not receive a response within 3-5 days, I will assume you do not want to participate.

Will I receive feedback on the results of this research?

The research will be protected under embargo for up to two years. However, if you are interested in receiving a summary of my research findings, I will share the abstract and some snapshots of the design process. Once the embargo is lifted, you can access the full published document and photographs of the final design outcome.

*This study is supported by **MBIE EXGware Master Scholarship** and the results of the study will be withheld under embargo from a maximum of 24 month from the completion of the Master's degree.*

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor.

Concerns regarding the conduct of the research should be notified to the *Executive Secretary of AUTEC:* ethics@aut.ac.nz (+649) 921 9999 ext. 6038.

Whom do I contact for further information about this research?

Sarah Pearson (Reseracher): phy6692@autuni.ac.nz

Stephen Reay (Project Supervisor): stephen.reay@aut.ac.nz

Please keep this Information Sheet and a copy of the Consent Form for your future reference.

Participant Information Sheet created 19/07/2021
Approved by the Auckland University of Technology Ethics Committee
AUTEC Reference Number: 21/285

2021-22 - AUT
Master of Design Research

Study Protocol: Trainee Dental Therapists

Research Objectives and Purpose

The researcher will engage in a non-invasive, non-medically active roleplay session from 1-3 third-year oral health students on-site at [redacted].potential participants will help the researcher understand patients' anxiety triggers and the role dentists play in managing dentally anxious patients.

Participants

1-3 [redacted]

Location

The active roleplay session will be carried out on-site at [redacted] at a time convenient to them. An oral health supervisor or staff member will be available on-site if assistance is required.

Duration

Roleplaying is expected to take between 30 – 45 minutes.

Recruitment

1. Poster adverts, including the researcher's email for contacting in case of interest, will be situated about the oral health clinic, study areas or locker rooms where students frequently visit approximately a month before the research start date.

2. Once potential student participants have contacted the researcher via email expressing their interest in participating, the researcher will send an email with further information and details about the research project with the PIS and consent form. Potential participants will have two weeks to consider participating in the study. A single follow-up email will be sent after two weeks if no response has been received and if no response, no further contact will be made. The researcher will reply and attach the consent form for signing and request dates for scheduling.

3. The first 1-3 potential participant to respond via email to the researcher will participate in the research. However, the following respondents will be excluded. An email will be sent out to respondents to confirm that no further participants are needed and to thank them for their interest.

Consent

The consent form will be digitally signed and sent via email or given physically on the day of the roleplay before the research proceeds.

What will happen? Roleplaying

4. The researcher will introduce themselves and the purpose of the exercise.

5. The [redacted] will explain treatments using dental devices (in a non-invasive and non-medical way, e.g. dental drills will be switched off, while the nurse explains what patients are told before receiving dental treatment. At some points during roleplay, dental devices might be turned on so the researcher can experience the sounds these devices make; often, these sounds are what heighten a patient's dental anxiety. However, these devices will be stationed away from the researcher and turned on for a maximum of 1-2 minutes).

6. To help the [redacted] explain what some of the behaviours of dentally anxious patients and the action are they would take to accommodate different patient's needs, 1-3 descriptions of personas will prompt each roleplay session.

Indicative Personas/ Prompts:

ersona 1:
Sarah
Age: 20

Sarah is coming in for her second visit after receiving news she needs a filling.
She is feeling very anxious because the vibrations and sound of the dental drill make her feel uncomfortable. She had told the dentist about her anxiety at her last appointment. However, her usual dentist is unwell, and she is greeted by a different dentist.

Questions:
- How would you greet Sarah?
- What signs might indicate her to be anxious?
- How might she react when the drilling starts?
- How would you help ease her anxiety?

7. The participants will be asked to describe what they are doing verbally and asked, from their experiences, to describe the behaviours of anxious patients.

For instance, "I am selecting the right tools to be used." Or "Now I am adjusting the dental chair to make the patient feel comfortable."

Collection of data

8. During and immediately after each roleplay session, the researcher will record data by taking notes of interactions, decision making, dialogue, and other interesting insights, such as the researcher's emotional responses during roleplay (for instance, recording anxious feelings triggered by different actions such as being lowered into the dental chair). Audio will be recorded in case any interesting insights are missed allowing the researcher to primarily focus on carrying out action roleplay procedures. Photos will also be taken by the researcher, participant, or staff member available on-site at [redacted]H to document each phase of the roleplay session.

Analysis

9. The researcher will analyse the data by sketching storyboards depicting each phase of a user's dental care journey provided with annotations transcribed from audio recordings or information noted during roleplay. The data gathered from these interviews and roleplaying activities will form the basis of the ideation process used to develop a series of concepts for feedback from patients and experts.

Participant Protection

Participants will be kept anonymous in any documentation of the data and will not be known to anyone except the researcher and supervisors. Images taken during the roleplay session will not show the participants identity. The participant can opt out of participating in the research project before data is analysed without being coerced or disadvantaged in any way.

Consent forms will be secured in a lockable cabinet in primary supervisor Steve Reay's office for six years.

Storage of Data

The audio recordings, notes, digitally scanned drawings, or other materials collected from the interviews will be stored on an external hard drive and secured in a lockable cabinet along with physical copies inside the [redacted]

Consent forms will be secured in a lockable cabinet in primary supervisor Steve Reay's office for six years.

Summary of Research

The published exegesis and final design outcome will be embargoed, so it will not be shared with the participant. However, a research summary/abstract and snapshots of the design process and key findings from the interviews will be shared with participants until the embargo is lifted and full access to the thesis is granted.

Research Objectives and Purpose
The research involves participation by oral health patients who perceive themselves as moderately dentally anxious. The involvement of patient participants will help give insight into how design can serve those who experience dental anxiety and improve dental care experiences for all. The project will explore how proven sensory-based techniques for stress relief and biofeedback systems can help alleviate dental anxiety.

Participants:
- Adults over 18 years old.
- Have experience with dental services.
- Have visited a dental clinic recently or within the last two months.
- Have experienced anxiety when visiting the dentist/dental services.
- Must be able to speak English.

Location: Where will the interviews take place?

Participants will be given a choice of two places for an interview [redacted] online as follows:

1. One-on-one Interviews:

Interviews will be conducted in a private room on-site at [redacted], primarily used for counselling sessions. These rooms are fitted with comfortable furniture and soundproofed doors for privacy. A supervisor or staff member will be on-site during participant interviews to ensure the researcher's and patient's safety. Participants can choose whether they'd prefer to give feedback immediately after their dental appointment or at another scheduled time that is convenient to them.

2. Zoom video call:

Participants will be given the choice of attending their interview via video call on zoom at a time convenient to them.

Recruitment:

Participants will be recruited through the [redacted] offers services across occupational therapy, physiotherapy, podiatry, psychotherapy, counselling, psychology, nursing, and oral health while giving [redacted] and [redacted] a real-life setting to learn skills and apply their knowledge. 'During patient consultations, students are supported and supervised by fully qualified and professional staff.' Registering patients consent to being contacted for research purposes.

3. Posters advertising the research project will be displayed on the [redacted] noticeboard and other places inside the health centre to notify visiting patients and staff. Participant information sheets will also be available for collection from the AIH noticeboard near the exit.

4. An invite email will be sent via [redacted] to patients who have consented to receive emails about research projects with the participant information sheet (PIS) attached, introducing the project and who is eligible. The invitation email will ask potential participants to contact the researcher via email. Potential participants will be given two weeks to consider and respond to the invitation. After two weeks, a single follow-up email will be sent as a reminder. Once potential participants have contacted the researcher, the researcher will reply via email and attach the participant information sheet and consent form ready for signing.

Consent
5. Consent will be collected in a written format scanned and sent via email, given physically on the day of the event.

What will happen?
6. Potential participants will be invited to attend two interviews. The first will be to understand people's experience of dental care and gain insights into how dental anxiety might be alleviated using sensory-based objects (e.g., weighted blanket, squeezy toys, wheat bag).

7. The second interview will be a follow-up to gather feedback on designed concepts.

Method
8. The researcher will start the interview by introducing themselves and the purpose of the project and interview. They will follow this with a short explanation of sensory modulation and biofeedback.

9. The researcher will then ask five semi-structured and open-ended questions related to the participant's dental care journey. For instance, how they felt and what things might have helped ease their anxiety—provided with some examples such as a weighted blanket, relaxing music, or visual prompt.

Indicative questions include:
- How do you feel about coming to the dentist?
- Can you describe this? Why do you feel this way?
- How anxious do you feel during a dental visit?
- What helps you feel calm in similar situations where you might be anxious?
- Describe things that help you feel less anxious?

- Have you used any strategies to manage your dental anxiety? If so, what were they and how successful were they?
- If sensory modulation methods (sensory-based methods) were available, when and how might you want to use them?

10. After the interview, the researcher will ask whether the participant wants to be involved in a second session. The participant may wish to schedule a follow-up session in advance or contact the researcher via email for scheduling later. The second session will occur at approximately two to four months after the first session to discuss design concepts. A reminder will be sent one week before the scheduled date.

11. In the second interview, participants will be invited to provide feedback on the researcher's design concepts prompted by five semi-structured open-ended interview questions. This secondary interview will help the researcher make critical design decisions and refine designed ideas. The researcher will start by introducing themselves again and reiterating the purpose of the interview and how their feedback will guide the researcher's thinking.

12. The researcher will show visuals, diagrams, or rough mock-up prototypes to communicate design concepts. Design concepts may be a calming object used to relieve tension during dental procedures or an object used in the waiting room to alleviate anticipatory anxiety. For instance, something soft and squishy they can squeeze as a distraction.

Indicative questions include:

- Have you had any thoughts you'd like to share about dental anxiety or your dental experiences since the last session?
- What concept stands out to you the most?
- How do you think you would use this? How do you think this would improve your dental care experience?
- Is there something you would like to add or improve to make this concept better?

Collection of data

All interview sessions will be audio-recorded, and notes will be taken. Any data exposing the identity of the participant will be removed during analysis to protect privacy.

Participant Protection

Participants will be kept anonymous in any documentation of the data and will not be known to anyone except the researcher and supervisors. The participant can opt out of participating in the research project before data is analysed without being coerced or disadvantaged in any way.

Analysis

The data will be analysed using thematic analysis to uncover key themes to support a human-centred design approach. The researcher will use the recorded audio to transcribe the interviews. Notes or and any other material such as sketches made by participants during the interviews or feedback sessions will be scanned and anonymised used to support design decisions and may be presented in the researchers written exegesis and other related academic publications. Participants will be invited to take original physical copies of any materials home.

Storage of data

The audio recordings, notes, digitally scanned drawings, or other materials collected from the interviews will be stored on an external hard drive and secured in a lockable cabinet along with physical copies inside the [redacted] organised by the project's supervisor for six years.

Consent forms will be secured in a lockable cabinet in primary supervisor Steve Reay's office for six years.

Summary of Research

The published exegesis and final design outcome will be embargoed, so it will not be shared with the participant. However, a research summary/abstract and snapshots of the design process and key findings from the interviews will be shared with participants until the embargo is lifted and full access to the thesis is granted.

Do you have dental anxiety?

Does the thought of going to the dentist/dental therapist fill you with anxiety?

I am looking for people like you to participate in my research project to design better dental care services for all.

Hi, my name is Sarah. I am the researcher and designer behind this project.

I completed my bachelor's degree in Industrial Design at Auckland University of Technology (AUT) and are now onto completing my master's. I believe design can positively change healthcare and strengthen communities.

What is the purpose?

As a designer, my job is to serve you, my potential users. I want to know how we can design better dental services which support your health and make you feel calm and relaxed.

Am I eligible?

You can participate in this study if you:

- ✓ **are an adult older than 18 years.**
- ✓ **experience anxiety when accessing dental care services and treatment.**

How do I agree to participate in this research?

Your participation in this research is voluntary (your choice), and whether you choose to participate will neither advantage nor disadvantage you.

Before meeting via Zoom for an interview with me, I will send you a consent and release form via email. Please read this form carefully before signing and sending a digital copy to my email address [redacted]

If you change your mind at ay stage of the project, you can withdraw from the study at any time, no questions asked. If you choose to withdraw, any data I have collected from you will be erased for your privacy.

Why have I been invited?

[redacted] contacted you because you have consented to be contacted for research purposes.

If you experience anxiety when accessing dental care services and are interested in participating in this study, please contact me.

What will happen?

The study will consist of two phases.

Before starting our conversation I will check with you to makesure you have read and understood the consent form or have any questions you wish me to answer. This part the interview will not be recorded.

Phase 1: I will ask you to critically reflect on your previous dental care experiences and answer questions.

Phase 2 (Optional): In this phase, I will show you visual and physical representations of my ideas for you to give feedback on.

Interview Structure: (30-45 minutes)

(a) Introduction: First, I will introduce the project and share some information about what happens when we are anxious and how these symptoms can be managed using relaxation and sensory-based techniques, which I will demonstrate using examples.

(b) Short Questionnaire: I will ask you to complete a short visual questionnaire, which you may use to reflect on your past dental care experiences, which should only take a few minutes of your time.

(c) Open-ended Interview Questions:

After this, I will ask you five open-ended questions related to your previous dental care experiences.

(d) Feedback (Phase 2):

Finally, I ask you to give feedback on my designed concepts.

When?

I wish to conduct the Phase 1 interviews in February and Phase 2 interviews sometime in late March to beginning of April (2022)

We can arrange a time most convenient for you via email.

Where?

Phase 1 of the interviews will take place via Zoom video call.

Phase 2 Interviews may take place in-person inside a public space such as a café at a convenient location to you or at [redacted]

Please turn page over.

If you choose to meet at [redacted] your interview will take place in a private counselling room, where staff will be close if you require any assitance.

Zoom video call

You can also participate via video call (Zoom) or phone call. This will not require a vaccination passport.

What are the discomforts and risks?

I will try to make you feel as comfortable as possible. But sometimes, our emotions get the best of us, and that's okay. Talking about negative dental care experiences may bring back some bad memories. This is a normal response which you should never feel ashamed of.

How will these discomforts and risks be alleviated?

If you feel uncomfortable answering some questions, please let me know. Your safety and comfort are of the utmost importance. We can skip ones you are not comfortable answering.

If, however, after the interview you still feel uncomfortable you are entitled to three free sessions of confidential counselling support at AUT Counselling and Mental Health. These sessions are only available for issues that have arisen directly because of participation in the research and are not for other general counselling needs. To access these services, you will need to:

- drop into our centre at WB203 City Campus,
- email counselling@ aut.ac.nz or call 921 9998.

What are the benefits?

You will be a part of positively shaping dental care experiences for the future.

Your involvement will help me develop a design outcome required to complete my Master of Design qualification. The design may be implemented in the future for helping to manage dental anxiety.

You get to learn too!

The design disciplines offer a new way of approaching and solving problems. I hope you leave feeling you have made a significant contribution and have gained a thing or two about design or some methods you might try in the future to manage your anxiety.

How will my privacy be protected?

Your name and any other information that may identify you will remain confidential, except to myself and my supervisors. You have the option of taking any physical material home, such as completed drawings or questionnaires. However, with your permission, I will digitally scan these materials after the interview for documenting.

I will make an audio recording of our interview to transcribe and write down any notes I may have missed during our interview.

What are the costs of participating in this research?

I only require your time and effort. However, travelling to [redacted] for the optional second interview (Phase 2) may incur some costs. We can offer a fuel reimbursement of $20 to help cover this cost.

What opportunity do I have to consider this invitation?

You have two weeks to communicate interest in participating. After two weeks, you will receive a follow-up email as a reminder. If I receive no response after 3-5 days, I will assume you are no longer interested.

Will I receive feedback on the results of this research?

The research will be protected under embargo for up to two years. However, if you are interested in receiving a summary of my research findings, I will share the abstract and some snapshots of the design process. Once the embargo is lifted, you can access the full published document and photographs of the final design outcome.

Please keep this Information Sheet and a copy of the Consent Form for your future reference.

*This study is supported by **MBIE EXGware Master Scholarship** and the results of the study will be withheld under embargo from a maximum of 24 month from the completion of the Master's degree.*

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor.

Concerns regarding the conduct of the research should be notified to the *Executive Secretary of AUTEC:* ethics@aut.ac.nz (+649) 921 9999 ext. 6038.

Whom do I contact for further information about this research?

Sarah Pearson (Reseracher):

Stephen Reay (Project Supervisor): [redacted]

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AUTEC Reference Number: 21/285

2021-22 - AUT
Master of Design Research

Appendix G

Example of Patient Journey Map executed on online Brainstorming platform Miro