University of Bergen
Department of Informatics

Master thesis in Software Engineering

Communicating Electroconvulsive Therapy Information via Web-based Narrative Medical Visualization

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Abstract

The essence of this project is to create an accessible, comprehensive and engaging information resource about electroconvulsive therapy in the form of a scroll-based website. Frequently abbreviated to just ECT, electroconvulsive therapy is a neurostimulating treatment that uses transcranial electric stimulation to treat moderate to severe mental health issues.

My core research focuses on investigating the use of narrative and medical data visualization as methods for communicating health data to a general audience. In particular, I focus on narrative portrayal of medical imaging-based data visualization, an area usually aimed at researchers and practitioners. I developed a website that combines such visuals and other produced material about ECT into an explanatory, interactive and engaging context.

With this, I hope to provide a counterpart to existing misinformation about electroconvulsive therapy. Medical narrative visualization is a potentially powerful tool that can be used to communicate crucial health data to those it concerns. However, little research exists to support this process. With electroconvulsive therapy as my application domain, I have sought to explore how a general audience experiences medical narrative visualizations.

Scientific environment

This project has been a collaboration between the University of Bergen, the Mohn Medical Imaging and Visualization Centre (MMIV), as well as the section for electroconvulsive therapy at Haukeland University Hospital in Bergen. They provided feedback through meetings and by partaking in the evaluation of the produced material. The degree is part of a joint study program in collaboration between the University of Bergen the Western Norway University of Applied Sciences.

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I want to thank Leif for giving me insight into the field of ECT. For spurring ideas for the project and sharing his thoughts and expertise. For keeping me in the back of his head whenever encountering literature that might be of relevance to the project.

I was allowed to partake in the user panel for ECT at Haukeland and present my project, and in turn gain valuable insight for the project. I want to especially thank to Ingunn Samnøy for reading through the written content of my website and giving me detailed and thoughtful feedback on the writing and routines. Also, to Kjersti Sellevåg, for showing me around the premises while explaining the ECT procedure, and allowing me to take photoes as a resource for the project.

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Sofia Hestenes Eika
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Chapter 1

Introduction

Autonomy is acknowledged as one of the major factors that contribute to life satisfaction [45]. The right to be governed by one's own principles can be seen as a backbone of many fundamental human rights, such as the freedom of speech or the right to education. Recent years in healthcare seem to reflect this thought. During the past decades, there has been a gradual increase in the degree of patient involvement in many healthcare systems[50]. The notion of the doctor as the primary decision-maker has shifted into one emphasizing consideration for the patient; a paradigm of healthcare termed patient-centered care [16]. It is a more collective approach that involves extensive collaboration between different clinical disciplines treating a patient, as opposed to a paternalistic model where a sole physician makes all decisions.

A core value of patient-centered care is the respect for patient autonomy, as well as regard for their relatives and significant others. One of the ways this is done is through *shared-decision making*[47].

The clinicians and patient determine therapeutic goals and interventions together. It is the clinician's responsibility to provide the patient with the necessary information and set aside the time required for them to partake in the decision-making process. This allows for personally acceptable terms that are consistent with the patient's beliefs, concerns, and preferences to be chosen [47]. Shared decision-making appears to be influenced by a number of variables, including the doctor-patient relationship, the time allocated for interaction and engagement, as well as physical and cognitive abilities [50].

According to Shortliffe and Cimino, comprehensive information about a patient's condition and viable treatment options should be presented in a way that is understandable and actionable to the patient [47]. Ideally, this information should be accessible, meaningful and easy-to-follow for anyone affected.

Helping patients actively collaborate and make educated decisions regarding their own health has been linked to many positive outcomes[50]; reports show higher satisfaction with care, lower costs and a more positive experience in clinical settings [25]. To an extent there needs to be a balance between control and freedom of choice for the patient. A patient, more often than not, lacks the competence necessary to properly comprehend the medical information that is provided to them [49]. Respecting their need to make individual choices should therefore be carefully guided by recommendations, knowledge of how data can interpreted and an account of the patient's situation. Effective strategies for communicating health information are therefore vital to the process of shared-decision making.

1.1 Overarching problem

A prerequisite for patient engagement is comprehension. Medical information presented should be understood by those it is intended for - regardless of socioeconomic status or circumstance. Although there exist structured tools to aid this process, a substantial portion of this responsibility is left to the caregiver. Knowledge transfer therefore still greatly relies on their ability to explain certain aspects of a treatment. Being aware of what strategies are effective, helpful, engaging, and less frightening to the patient is therefore interesting to know when explaining a medical procedure with data, or when creating patient resources for individual consumption. Addressing and being mindful of some of the potential vulnerabilities to this approach is helpful when attempting to construct meaningful patient information. A starting point is looking at how different types of information are *perceived*, and how the *presentation format* affects this perception.

1.1.1 Approach

Visualizing data is a potentially powerful tool that may aid knowledge transfer. Graphical representations of data can capture a viewer's interest and provide a compelling way of communicating data that may be difficult to relay with words alone. Visuals offer a unique way of displaying patterns, create focal points and may utilize associations, colors and metaphors to convey meaning to the patient.

Medical visualizations today are primarily created to aid medical researchers, practice, education, and to some extent doctor-patient dialogue; rarely patients alone [14, 34, 49]. Therefore, little attention has been paid as to how this stimuli is perceived by those lacking the medical competence to fully comprehend it. For instance, if a patient with a brain tumor is handed raw neuroimaging data without explanation, they will most likely be left none the wiser. It is reasonable to assume that patients need more context, guidance and explanation for these sorts of visualizations for them to be helpful. How variations of medical visualizations are **perceived** is one of two topics of research that this thesis explores.

Narratives are one of human kind's oldest ways of giving structure, context and memorability to information. Successfully combining data visualization and narratives can contribute to making messages that are informative and easily consumable. Interactive data stories have gradually increased in popularity these last few years, but more so in other topics of science than medical visualization [34]. Presenting health data as a **visual and interactive story** is the second topic of research in this thesis. A particular interest is paid to those with without medical background knowledge and limited familiarity to scientific visualizations.

1.1.2 Vulnerabilities

Medicine is an advanced and vast academic field; a great deal of formal training is needed to acquire fundamental knowledge. Traditionally, areas like law and medicine have been exclusive to those with enough resources and capability to immerse in them. Due to the fields' complexity and historical development, terminology and material can be hard to comprehend for those without this training. When showing non-experts medical visualizations one should explicitly address this lack of knowledge by carefully examining how stimuli are perceived and interpreted.

A realistic understanding of probability linked to risk and effect is cruical to a decison-making process. The field of cognitive psychology has taught us that humans are, generally speaking, notoriously bad at intuitively understanding statistics. People often struggle to make distinctions in probabilistic outcome;

this is illustrated by Tversky and Kahneman who have identified several cognitive fallacies[32, p. 421-429]. People tend to ignore the likelihood of each outcome (the base rate), and the fact that singular statements are more likely to be true than conjunctional ones. Conclusions are often inferred from patterns that come across meaningful, but are actually accidental. Humans often have difficulty distinguishing between correlation and causality, and overestimate the statistical significance of events that are recent or emotionally touch us. These are just a few examples. A number of cognitive problem-solving heuristics make us capable of efficiently producing solutions for complex problems [32, p. 380-381], but also render us susceptible to ”mental shortcuts” that can be a source of misjudgement.

Varying degrees of health literacy, cultural background, medical conditions, as well as other common sources of misconceptions is a topic of interest in this thesis. For example, research on graphs and color maps show that they differ in their ability to communicate data well. People differ in their interpretation of different representations of information, such as metaphors and abstractions [3]. We will take a look at some of these topics in Chapter 2.

1.2 Project description

The practical objective of this project has been to create a compelling source of information about electroconvulsive therapy in the form of a website. It is a resource intended for patients and anyone curious about the treatment. The website is developed in React, a JavaScript library that uses functional components. At the time of writing, the project is stored locally (i.e. not hosted online). I have created all material and functionality on the website for this thesis.

The content of the website is written in Norwegian. This was recommended by co-supervisor Leif Oltedal as it might be of relevance to Helse Bergen as a patient resource. The site contains information on indications for treatment, a description of the written consent form needed prior to treatment, as well as what happens during and after treatment. Infographics are used to present possible beneficiary and adverse effects. One section displays real, anonymized patients' experiences with the therapy. Another shows what happens to the brain during electric stimulation, and the most common form of electrode placement. The page follows the fictional patient "Åse" who undergoes treatment.

An active attempt to make the architecture of the website as generic as possible has been made. As a result of this, the code can be reused for different purposes and support different kinds of content. The website supports various ”post types”, so that format of a post can be adapted to it's content and desired narrative style. One can easily switch a post from one kind of post to another (e.g. scrolling text over images, zigzag pictures and sticky images along with text).

1.2.1 Background

The following subsection lays out the background and motivation for this initiative. It starts by explaining the application domain, electroconvulsive therapy, and the driving factors behind creating a resource for non-experts.

1.2.1.1 What is electroconvulsive therapy?

ECT is the most acutely effective treatment to severe treatment-resistant depression [42, 51, 43]; that is, depression where other interventions such as pharmacological agents and therapy have had limited or no effect. Clinical trials indicate that remission of depressive symptoms in this group occur in more than half of those who receive it [22, 28, 24, 13]. Subtypes of psychotic depression and elderly depression in particular are shown to be indicators of a beneficiary response to ECT[8]. A wide range of neuropsychiatric disorders are treated with ECT, with indications for treatment varying with geographic location. In Norway, indications for treatment range from moderate to severe treatment-resistant depression, some forms of bipolar disorder, post-partum psychosis, depression amongst senior citizens, depression in patients with intellectual disabilites, catatonia, schizoaffective disorders, and patients at risk of suicide or severe self-harm [20]. Asia, Africa, and parts of Eastern Europe treat schizophrenic patients with ECT, but this is not as common elsewhere, including Scandinavia.

ECT is a safe and gentle treatment well-established in modern medicine. It is associated with far less dramatic adverse effects than when it was first performed [22]. The treatment is administered in over 50 hospitals in Norway [40]. It is given as a series of individual sessions, where the patient is placed under general anesthesia each time [28, 42, 24]. A controlled amount of electricity is administered for up to eight seconds to the patient's head; the electricity intentionally invokes a brief seizure that can last for up to a minute. Consequently, a short period of heightened brain activity can be observed. Muscle relaxants given prior to the shock prevent any major convulsions. During and after the treatment a lot of patients experience a substantial relief in their depressive symptoms. However, if adequate aftercare is not provided, many patients experience relapse after receiving ECT [22, 28].

Traditional intervention, such as psychotherapy and pharmacological treatment, often require considerable time and effort. With ECT improvement is frequently seen within two-four weeks of starting treatment [51]. Due to this fact, it is viewed as a particularly well-suited alternative for those who exhibit strong suicidal intentions [22, 28].

Short term adverse effects can include nausea, head-aches, muscle-aches, dizziness, confusion, fatigue, and short-term retrograde amnesia (i.e. short-term memory loss) [28, 24]. These usually improve during the course of the treatment. Generally, fewer cognitive side effects are associated with right unilateral electrode placement (RUL) compared to bilateral placement [28]. Long-term adverse effects are not as frequent, but do occur. Complaints normally involve subjective cognition, such as a reduced concentration span and experiences of loss of long-term episodic memories. Autobiographical memories are usually less affected than those of an impersonal character, such as events or incidents [29]. Early animal studies on ECT have shown a brief interruption in *long-term potentiation* in the hippocampus [42], a mechanism where synaptic connections are strengthened. Confusion and short-term memory impairment during and for a short time after ECT may be explained by a similar effect on humans.

The underlying mechanisms of ECT remain unexplained. Important discoveries are articulated and summarized in a literature review of its neurobiological effects [42]: ECT disrupts and stimulates the neural network in the brain, causing chemical changes that improve mental state. MRI is used to non-intrusively study these impacts. Research on structural changes in the brain due to ECT show an overall increased neural plasticity and neurogenesis. This means that the neural paths in the brain are more susceptible to change and that new neurons form. Additionally, a volumetric increase is seen in grey matter/several regions in the brain, such as the hippocampus and amygdala. This volumetric expansion is positively correlated with the number of treatments. Studies reveal a lower level of brain plasticity in depressed individuals, who frequently exhibit rigid, negative thinking patterns. This increase in plasticity resulting from ECT may, albeit speculatively, facilitate the cognitive flexibility required to rewire to more healthy patterns of thought during and after treatment.

1.2.2 Motivation: Why create a patient resource?

The World Health Organization prognosticate that depression will be the primary cause of disease burden worldwide by 2030 [52]. This prediction stems from a report they presented in 2012. In this report they wrote that unipolar depressive disorder accounted for a third of the world's disease burden. Severe mental illness were linked to the highest unemployment rate, which ranged up to 90%. People who struggle with major depression and do not respond to, or for other reasons cannot take, medications suffer a significantly reduced quality of life. The risk of death in this group is up to 1.4 times higher than the population in general, linked to physical health problems (e.g. cancer, diabetes, HIV), and suicide [52]. ECT has the highest remission rate for reducing depressive symptoms in this group; as a result, it is a tool that may enhance overall quality of life and lower societal expenses related to medical care and diminished job capacity. Literary reviews of the use of ECT suggest that the treatment is underused [13], and often terminated prematurely [28].

Mental health issues warrant a lot of stigma in general. ECT has been, and is still, a controversial treatment to many [47]. ECT was first practiced by two Italian doctors named Ugo Cerletti and Lucio Bini that worked in a psychiatric ward in the late 1930s [22]. Inspired by the ideas of a Hungarian physician, they started experimenting with schizophrenic patients; they induced seizures by administering doses as high as a 100 volts of electricity to their head without anesthesia. These experiments were likely performed without consent, and the patients were awake but would often eventually lose consciousness while receiving treatment. The convulsions were often so dramatic that patients fractured bones during the seizure. ECT was less frequently used with the introduction of pharmacological treatment for depression in the 1950's [28].

In a Norwegian master's thesis named *Patient experiences before, under, and after Electoconvulsive therapy*, several interviews with patients were conducted and transcribed [15]. A portion of the interviews reveiled that patients often had low general knowledge of the procedure prior to treatment. Many of the comments indicated that patients were frightened: *"I was scared to death that it might destroy something in my head, that it was a modern form of lobotomy"*, *"Just the thought of my body being shocked, and I was scared of the effects after treatment... It was the picture of ECT and what one had heard and seen in the movies that scared me."*, and *"I had thoughts about what I'd seen in the movies, like 'One Flew Over the Cuckoo's Nest and things written in the media"*. Frid, the author, stated that most of the participants only had knowledge about ECT from media the first time it was presented to them.

The film "One Flew Over the Cuckoo's Nest" was also frequently mentioned by others when describing *this project* to acquaintances. A short description is included below to impart what these associations may entail. The film is adapted from Ken Kesey's book from 1962, and portrays a psychiatric ward in Oregon in the 1970's. In one of the scenes of the movie the main character Randle, played by actor Jack Nicholson, receives ECT against his will. He is led into a room full of people and told to lie down. With no information given, they administer ECT bilaterally while he is awake and is held down by eight people simultaneously. The scene is generally inhumane and hard to watch. The piece is recognized as a critique of earlier treatment of patients in psychiatric institutions.

These portrayals of ECT bear little resemblance to how the procedure is performed today [22]. ECT is always administered under anesthesia and with muscle relaxants preventing any major convulsions. The shock strength has been reduced drastically and is always kept at a minimum where desired effect is attained. Unilateral placement of electrodes are shown to have less adverse effects than bilateral electrode placement [31], with no change in overall efficiency. According to Norway's national guidelines for ECT, the treatment is only given without consent in situations that are life threatening or where grave health risks follow by not intervening [20]. Despite this development, the history and negative associations to the treatment still seem to linger.

Another qualitative study (2021) in Norway performed in-depth interviews with ECT patients about their experiences with the procedure [10]. Several patients from this study explain that ECT was presented to them as *"a last resort"*, and that the treatment felt like *"it was their only option"*. Many of the interview subjects were dissatisfied with the amount of information given to them about the treatment, and would have liked to receive more prior to consent. Some reported that they questioned the validity of their consent. An important adverse effect of ECT is the risk of having issues with memory, both short and long term. All participants were reportedly worried about possible memory loss. Explanations from health professionals were stated as being calming and stress relieving. A portion of the subjects said that they remember being told differences between historic and modern ECT, but do not remember signing a consent form. An overall frustration over lack of knowledge and availability of general information were reported. Participants were particularly interested in statistics, brain science, and other patients' coping strategies.

Creating an accessible patient-resource for ECT may prove advantageous in a number of ways. Although conjectural, it could be advantageous to create a patient resource that is static and can be read "on demand" in addition what is told the patient through consultations with their psychiatrist and other health professionals. In this way, some of their questions may be answered if any of the information relayed in person is forgotten. Visuals may offer more memory cues than orally given information alone. More meaningful patient-doctor interactions can take place if the patient already has some form of understanding to what the treatment is, and what questions to ask. By canalizing search online to a known, reliable source meant for patients, there may be less exposure to misinformation on the internet. It could also provide a counter-balance to existing misinformation as well as the prejudice and negative associations cultivated by popular media and the film industry. Increased access to knowledge about the treatment might reduce stigma directed towards those who receive it [10].

Due to existing prejudice it is interesting to investigate narrative medical visualization as a communicative medium for a treatment like ECT. Ideally, medical images might demystify the procedure and help patients gain a deeper understanding of the treatment. The content will be easier to process due to its narrative structure, and might also seem more approachable. On the other hand, if not executed well or the medium proves not to be suitable, the opposite might be true. The medical images might frighten patients and the narrative style gain critique for appearing too anecdotal for a treatment that arguably already struggles with an image problem.

1.3 Research topic

This research topic of this thesis is how visualized health data about ECT is **perceived by a general audience**. This is motivated by a desire to understand whether narrative and medical data visualization might be applied to promote shared-decision making and general health awareness. My approach is based on a review of scientific literature and qualitative external evaluation of the visualizations produced here.

1.3.0.1 Research questions

- Investigate how *medical data visualizations* related to ECT are perceived. More specifically:
  - Do non-experts want to be shown medical data?
  - What are preferences when shown medical data?

        * Are there, and if so, any preferences in angles of given visualizations?
        * Associations, thoughts, and opinions about various color maps?
        * General or specific preferences on two-dimensional (2D) vs. three-dimensional (3D) views?
        * Degree of supplementary explanation desired for a visualization.
        * What are preferences in level of realism/abstraction (i.e. detail level of data visualization)?
        * Level of perceived comprehension.

- Investigate the use of *narrative data visualizations* as a tool to communicate health information about ECT. More specifically:
    - Ability to contextualize medical visualizations.
    - Interactive methods.
    - Use of illustrations, isotypes and symbols.
    - Types and variations of graphs.

- Data visualization in general: What are important aspects?
    - Clarity?
    - Context?
    - Comparison?
    - Aesthetics?

1.3.1 Contribution

The practical and theoretical contributions of this thesis are listed below. Key findings are listed in the chapter 6.

- An information page about ECT available to Helse Bergen as a patient resource.
- Source code for the project. The code is intended to be generic; it renders a headline, menu and posts dynamically based on some parameters (given text, post type and images). In other words, it would be relatively simple to create a similar, but customized, website for another treatment or other purpose.
- Qualitative evaluation of how medical visualizations about ECT, made for a general audience, are perceived. This was collected through feedback from both medical experts and non-experts. Most scientific focus on medical visualizations are, to my knowledge, mostly aimed at medical researchers, practitioners, and for educational purposes.
- Qualitative evaluation the website using narrative visualization techniques to convey health information about ECT. Again, to the author's knowledge, not much attention has been previously been given to narrative visualization used in a context with communication about treatments.

1.3.2 Limitations

This thesis is an applied case study of medical narrative techniques. The visualizations created and evaluated here are therefore a strictly related to ECT. The project investigates this subject only through the selection of visualizations and website created for this specific purpose. Therefore, it is challenging to determine how generalizable the results reported here are. Further limitations are discussed in Chapter 6, Conclusion.

Chapter 2

Preliminaries

This chapter describes related work. It is part of the research done prior to creating the content and visualizations presented in this thesis. The project scope touches a wide range of academic disciplines; parts of the preliminary research has been omitted from this chapter to stay within the purview of computer science and stated research topic (1.3.0.1). The more practical components of this thesis, such as the workings of the application used to simulate an electric field on the brain, web development and React are described in Chapter 4. Presented below are topics in *medical narrative data visualization* relevant to this thesis.

2.1 Data visualization

An integral part of empirical research is making observations about data; data is carefully structured and analysed in an effort to extract possibly insightful information about a phenomena. Data visualization is the process of *graphically* representing data. Tamara Munzner defines data visualization like this[37]:

"computer-based visualization systems provide visual representations of datasets intended to help people carry out tasks more effectively". Humans have a highly developed perceptual system; outliers, patterns, and tendencies frequently become almost inherently apparent when presented to us visually. Thus, visuals like maps, graphs and illustrations are valuable tools for studying and communicating data.

Practical use of data visualization is ubiquitous in technologically developed parts of the world. Following the last decades of technological advancements, tremendous quantities of data are now being generated, collected, and analyzed daily. Data visualization enables us to effectively act upon this data in a way that otherwise would have been virtually impossible.

Visualizations serve as a tool in a wide range of decision-making activities; medical imaging diagnostics, sales strategies, engineering, and scientific research are all reliant on quality depictions of data. Thus, it is of essence to ensure that these portrayals accurately reflect the underlying data. Effective data visualizations are able to eliminate noise and draw attention to key details; inefficient visualizations, on the other hand, have the ability to obscure, distort, and introduce artifacts not present in the data[35].

2.2 Color maps

In spatial data visualization, data points have an inherent location. For example, in scalar fields, every location has one data value. When certain colors are assigned to each placed data point, a visual structure such as surface or volume emerges [35]. The collection of colours that are mapped to a scalar field, is known as a *color map*. Color maps are either single- or multi-hue schemed [30]. A multi-hue scheme contains several colours (e.g. blue, green, yellow), whereas a single hue color map contains one colour with various levels of luminance (e.g. light to dark green). This subsection will discuss characteristics of color maps as they are presented in literature.

Scientific research routinely and widely employs *Rainbow* color maps [35], illustrated in figure 2.1. Many members of the visualization community have expressed their disapproval of this color map. The shortcomings of this scheme are summarized by in various papers by Lui and Heer, Borland and Taylor, Light and Bartlein, Moreland, and Crameri et al. [30, 7, 27, 35, 11].

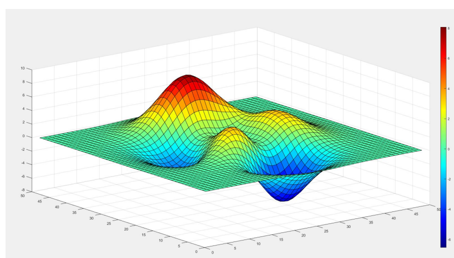
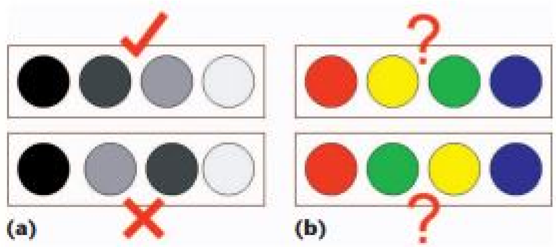


Figure 2.1: Rainbow color map illustration. Specifically, one of MATLAB's default color maps, **Jet**.

The rainbow color map spans all hues in the spectrum of visible light [35]. As a result of this ordering strategy, an important deficiency is that it is not perceptually ordered. That is to say that it has no natural ordering intuitive to human perception. This is illustrated in figure 2.2. The lack of perceptual ordering becomes evident when one fails in the task of reverse mapping colors back into numeric values [35].



1 Perceptual ordering. (a) We can easily place the gray paint chips in order based on perception, (b) but cannot do this with the colored chips.

Figure 2.2: Example of perceptual ordering. Figure borrowed from Borland and Taylor [7]; ©2007 IEEE.

A second point is that it does not regard those with impaired color-vision. Deuteranopia, or red-green color blindness, affects around 5% of the population [35]. Color-vision deficit is far more prevalent in males than in women because the illness is implicated by a recessive gene associated with gender [27]. Therefore, men account for a substantial portion of the 5% population estimate. Depending on the deficit, colours from figure 2.2 would not only lack perceptual ordering, but certain colors rendered indistinguishable. Therefore, it is in general quite problematic to choose color maps that do not take this group into consideration [11].

The rainbow color map lacks perceptual uniformity. Blue, red, and green areas of the color maps appear proportionately larger than the yellow and cyan regions [35]. This creates a disproportionate correspondence between numeric values and corresponding color, effectively obfuscating data. A final remark is that it struggles to convey information in regions with high spatial frequency [27]. Details and sharp edges of the data are most optimally conveyed through changes in luminance [30, 7]. The rainbow color maps changes in colors at the boundaries mostly between hues [7]. Consequently, gradients are not effectively communicated either.

Van der Walt and Smith have created four multi-hue color schemes: *Viridis, Magma, Inferno,* and *Plasma* [39]. These are generated by scaling hue and brightness at the same time through a perceptually uniform color model [30]. These are perceptually ordered and color-vision deficit friendly. Printed black and white versions of visualizations are also still reliable. Figure 2.3 provides a comparison of Jet and Viridis from several color-vision deficit points of view.

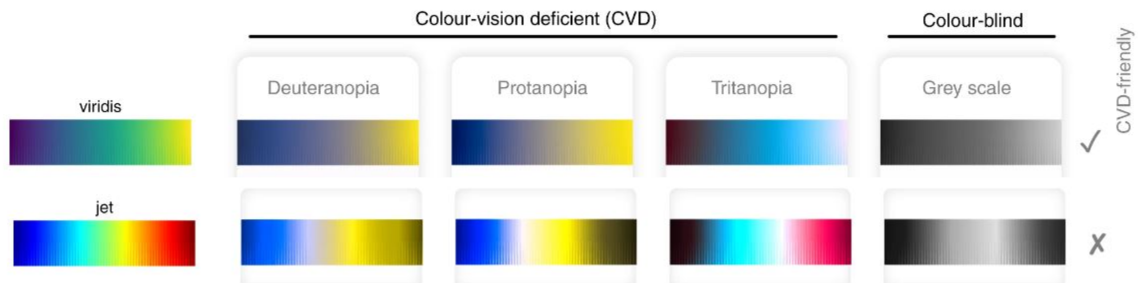


Figure 2.3: A comparison between **Viridis** (top) and **Jet** (bottom) in terms of color-vision deficits. Figure borrowed from Crameri, Shephard, and Heron[11]; ©2007 Creative Commons Attribution 4.0 International License. The figure has been photographically altered to exclude other color maps not mentioned here.

The inadequacies of the rainbow color map highlight some elementary considerations to bear in mind when selecting color maps. While no color scheme seems to be completely effective at communicating all types of data, some are consistently outperform others in terms of accuracy and overall consistency. Advocates of the rainbow color map state that the varying hues are helpful in making distinctions between ranges in data [30]. Experiments show that single-hue color maps are generally more adept in conveying changes in gradients, but perform poorly on data sets with small ranges in data [30]. The perceptually uniform multi-hue color maps described in the previous paragraph are are better suited in 2D models compared to 3D, as their luminance is known to sometimes interfere with shading from light. However, in experiments that measure accuracy and speed of interpretation, they perform better than the previous ones.

This thesis's research question focuses on how non-experts perceive various color maps used in transcranial electric stimulation simulations. Based on this chapter's research, I have chosen to include a rainbow color map, some of the perceptually uniform multi-hue color presented by Van der Walt and Smith, and single-hue pink color map intended to mimic the color of a real brain. See figure 2.4. I am curious of what associations these color maps evoke, so that this may be a future consideration when choosing color maps for non-experts.

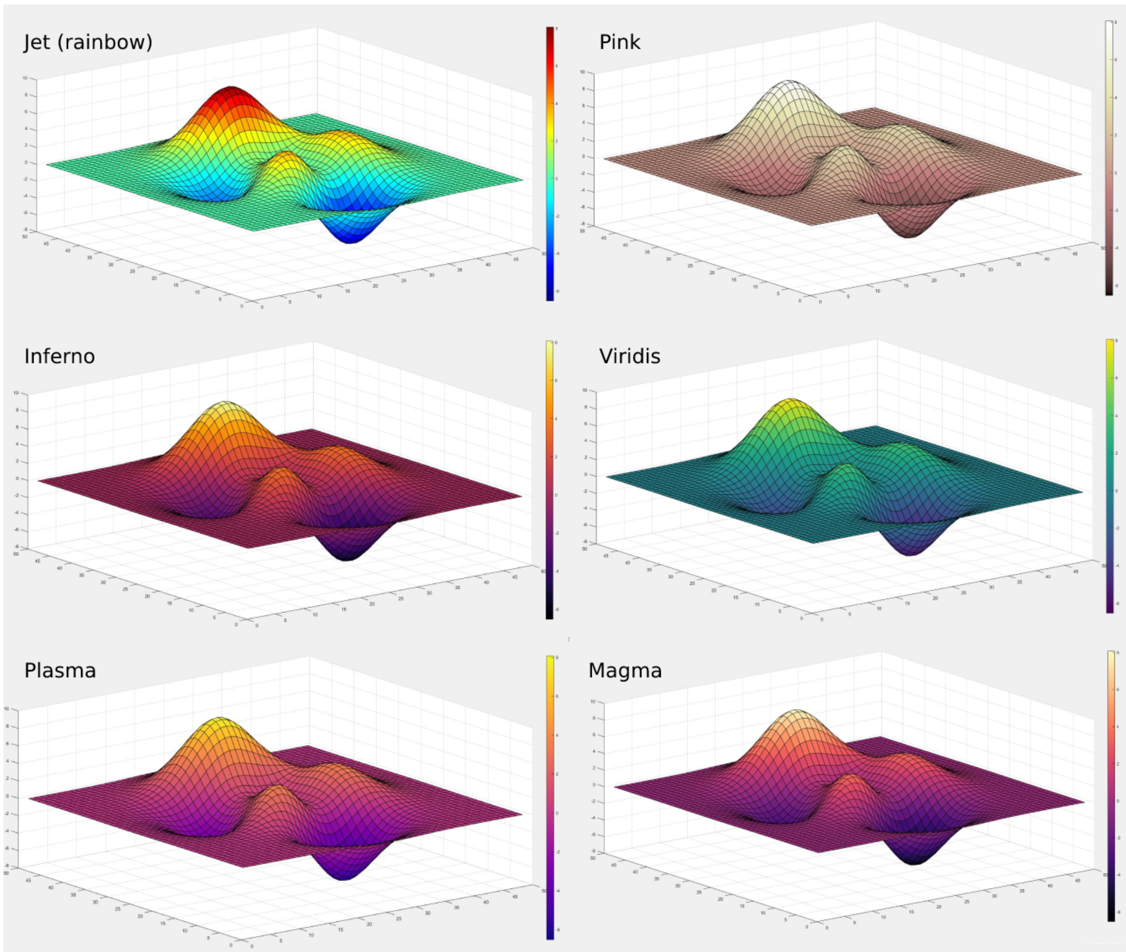


Figure 2.4: Color maps utilized in this project. Jet and Pink are predefined in MATLAB. Inferno, Viridis, Plasma, and Magma were created by Smith and Walt [39], and made available under a (CC0) Creative Commons License. Repackaged for MATLAB by Biguri [6].

2.3 Medical narrative visualization

Narrative visualization is the act of creating a story of data that a user can explore. This type of storytelling differs from others in that it is typically reactive; some level of engagement is required from the user in order to reveal the narrative. In medical narrative visualization the content of such a story consists of **health data**. Explanatory visuals may help clarify complex medical data, especially when contextualized with a *"who, what, why, where, and when"* usually present in a narrative [46]. A goal of narrative scientific depiction of data is to make it more widely accessible. Making health information easier to understand and consume may promote public awareness and the active engagement of those it directly concerns.

Segel and Heer provide a comprehensive review of narrative techniques through their paper *Narrative Visualization: Telling Stories with Data* from 2010 [46]. They present seven genres of narrative visualization, identify numerous different visual techniques, and describe various narrative patterns. They provide an analysis of five concrete examples and highlight successful and less successful elements of data communication. By combining these principles with an analysis of disease information, Meuschke et al. have created a template for medical narrative visualization of diseases [34]. Böttinger et al. have written about reflections for scientific visualization aimed at a broad audience [9]. The remainder of this section will distil relevant insights from this, and other, reviewed literature.

More and more news agencies are adopting an interactive narrative style transcending that of traditional articles. Recent examples are the numerous data visualizations made to illuminate data relating to the Covid-19 pandemic, as pointed out by Meuschke et al. This is illustrated in figure 2.5. Many contain maps of countries or continents where you can hover your cursor over a region and look at specific statistics for that area. The pacing and depth of exploration is then determined by the user.

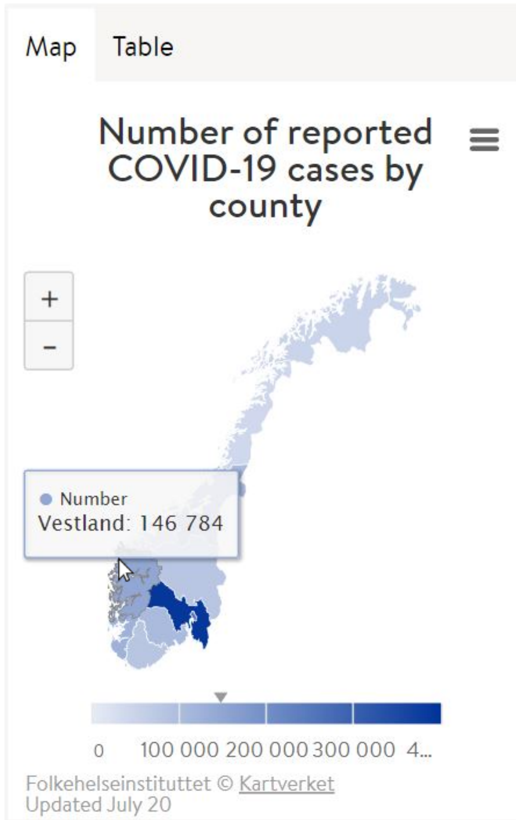


Figure 2.5: Registered covid-19 cases by county in Norway. A mouse hover will reveal data linked to a specific region. An example of how interactive visualization can be used to explore data. Credit: Folkehelseinstituttet © Kartverket.

A distinction that can be made to storytelling is whether it is *synchronous* or *asynchronous* [26]. Synchronous storytelling denotes a narrator in direct contact with the listener. This is for instance a public speaker talking to an audience or someone telling story at an assembly around a campfire. Asynchronous storytelling does not necessarily have this direct connection to a listener, such as the narrator in a book or a film. A story can be said to consist of *story pieces*, factual information supported by data and presented in a narrative[26].

The genres and narrative style of a story should be suited to its target audience and communication goal [34]. Segel and Heer identify seven genres of narrative visualization: magazine style, annotated chart, flow chart, comic strip, slide show, and video. A story can consist of a combination and is not strictly bound to be one or the other. Narrative structures are not constrained to a determined pattern. Structures can alternate between free exploration with self-chosen paths, design guided progress, or a linear path. A pattern declares how *author-driven* or *reader-driven* a narrative is at any given point of the story. Three common patterns are described by Segel and Heer. A martini glass structured story starts with an author-driven narrative and then becomes more open and exploratory towards the end. An interactive slideshow allows for open interactivity and exploration in each slide, but the slide order is fixed. A third pattern is a general topic with several sub-themes that the reader can delve into for deeper insight. The mentioned genres and patterns are illustrated in figure 2.6.

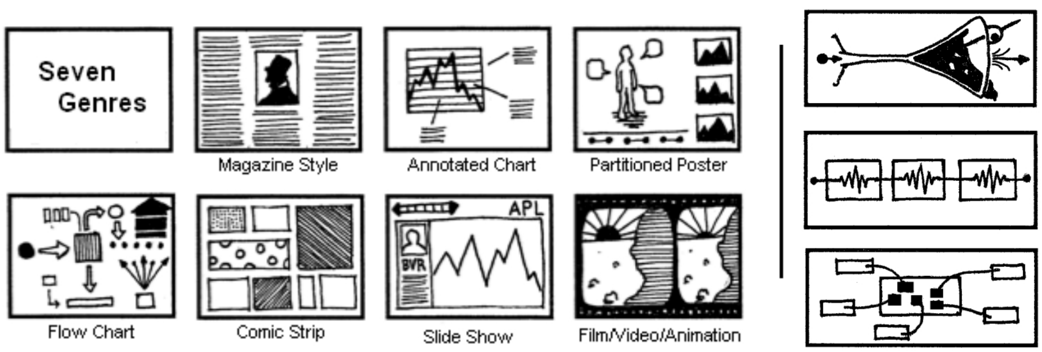


Figure 2.6: Seven proposed genres of narrative visualization to the left; three common narrative patterns to the right (from the top: Martini, interactive slideshow, . All figures borrowed from Segel and Heer [46] © 2010 IEEE.

2.3.1 Visual techniques

Humans are inherently prone to seek out patterns and logical connections in order to arrange the world into meaningful categories. From an evolutionary perspective, this is what makes humans able to adaptively and efficiently interact with the environment. Narrative visualization can benefit from this by using *visual techniques* and cues to create engaging stories by highlighting points of interest and minimizing visual clutter.

Visual techniques can be especially helpful in guiding the reader through a data visualization. Segel and Heer describe **visual salience** [46] in which certain visual stimuli stand out among others. Selecting a visual platform devoid of vibrant colors and then emphasizing particular elements with more prominent colors can help create visual salience. Dark backgrounds can be used to make contrasting colors stand out more compared to that of a white layout. The **search pattern** when visually scanning a page appears to be culturally conditioned. Western cultures read from left to right, thus their search pattern usually begins at the top left of a page [46]. **Consistent colors** can be used to link belonging elements together, such as when graph data matches its corresponding label. **Gestalt grouping** is a tendency to group elements together when they are in spatial proximity of each other [46]. Another gestalt principle for grouping applies to elements that are **similar** to one another [48, p. 208].

Giving **details on demand** rather than to present all information at once is another visual design strategy. This allows the user to actively explore data, pursue their interests, and reduce visual stimulation. A **consistent visual platform** may reduce cognitive load associated with reorienting in a new environment. This principle may be especially important to this thesis as the target group mainly consists of severely depressed patients. **Points of comparison** allows a user to contextualize data, often by comparing numerals with meaningful associations. **Annotations** are text labels that provide explanations for displayed data. **Animated transitions** between objects does not allow for active exploration, but can symbolize the relation between components or scenes. Interactive design strategies include **markers of interactivity**, such as lighting up on cursor hover. Some of these principles are illustrated in figure 2.7.

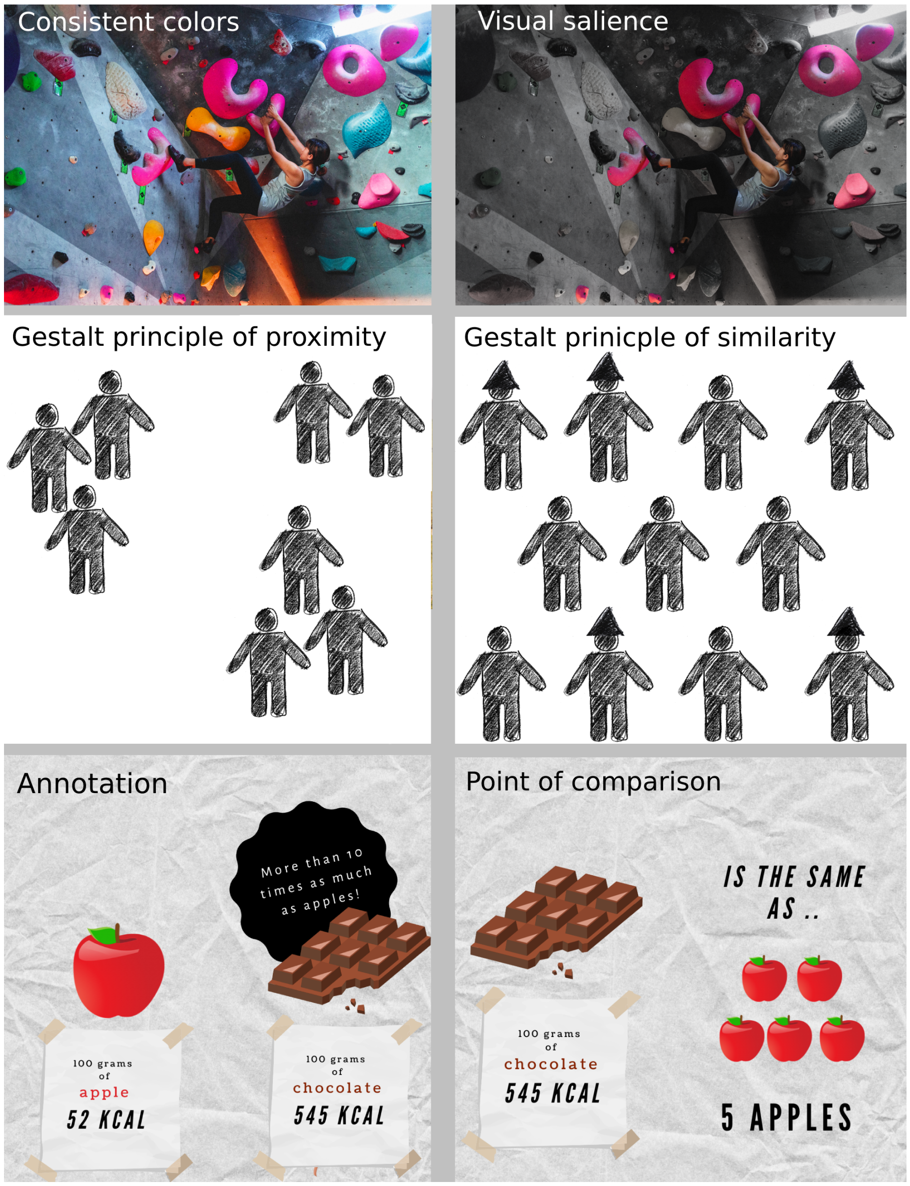


Figure 2.7: Various visual design strategies for data visualization. Pictures horizontally have intentionally been created with **consistent visual platforms**, another visual technique. The caption of each picture is placed in the top left corner to facilitate fast orientation; with a disclaimer that this **search pattern** is biased towards cultures that read from left to right. Examples made with free to use images from Pexels and Canva.

2.4 Challenges

The primary audience for medical visualizations has traditionally been scientific researchers, clinicians, and higher education students[34]. As mentioned briefly in the introductory chapter, medicine has not been subject to the same scientific outreach as astronomy, climate and biological data [34]. Böttinger et al. discuss ***challenges*** to consider when developing visualizations for a more heterogeneous audience with varying degrees of background knowledge and motivation [9].

One challenge is to be aware of the target audience of a visualization, and adapting its design to reflect who the message is communicated to [9]. Goals and characteristics of the target audience should be identified to do this, according to Böttinger et al. Domain experts have the required knowledge and usually intrinsic motivation to examine a scientific visualization without further facilitation. A general public can be composed of a wide variety of people of different ages, cultures, education levels, geographic backgrounds and varying interests. They may lack both the necessary competence and motivation required to view such a stimulus. Thus, exciting and understandable material tailored for this group may create the incentive needed to trigger curiosity. Multidimensional visualizations may be created for a wide audience so that persons with differing levels of expertise will find them fascinating. Garrison et al. offer a relatable example of this through Pixar's animated films [17]. Though children are a large target audience of these films, layered references to teenagers and adults enrich its narrative without being noticeable to the younger crowd.

Another issue is to perform an appropriate amount of abstraction of data [9]. Transforming complex data into a meaningful visual structure often requires some simplification, especially when portraying it to an audience with no background knowledge. According to Bottinger et al., this process should be executed with care as information reduction could be interpreted as willful omission of details [9]. An additional ethical aspect is utilizing the visual techniques discussed above while still representing the underlying data truthfully and highlighting actual points of interest.

The data visualizations and design choices for the website are greatly influenced by the reviewed literature on this topic, and is explained in detail throughout chapter 3 and 4.

2.5 Comprehension across varying levels of health literacy

Health literacy can be understood as *"the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions"* [44]. Presenting data through visual graphics may be a valuable aid in imparting vital health information in a way that is comprehensive, engaging, accessible, and actionable. Studies have demonstrated that there are features that enhance or impede comprehension of health graphics [3, 19]. These try to identify which characteristics of visualizations that are generally well-understood and which are frequently misinterpreted or disliked. This section will state some of these characteristics and provide an insight into what various studies have discovered.

Community members of **low health literacy** or numeracy may especially benefit from visual display of their health data [33]. Social determinants such as limited education, older age, chronic diseases, and being a non-native speaker are associated with lower health literacy [21]. Additionally, these individuals show a reduced ability in disease management and self-care, and have an overall higher mortality rate. Reduced comprehension and language barriers for ethnic minority groups serve as a challenge to efficiently provide the necessary information needed to engage in their own health [33]. Consequently, special interest is placed on individuals with marginal or inadequate health literacy throughout this section.

Arcia et al. presents three separate iterative participatory design studies for evaluation of tailored infographics [4, 2, 3]; these are outlined and summarized in a paper by written by Arcia [1]. In these studies, infographics are constructed in collaboration with a group of health and biomedical informatics experts [3], a graphic designer, a nurse scientist, and domain experts [2, 4]. A large portion of the participants in these studies were Hispanic (95% of 102 participants, 100% of 16 participants, and 38% of 21 participants). The surveys were performed in Spanish or English. A large portion of the participants were determined to have marginal or inadequate health literacy (53%, not measured, and 71%). During the surveys they discussed the illustrations and assessed level of comprehension, what their preferences were, and notes for improvement. They regarded comprehension as whether or not an infographic was interpreted as its authors intended [3]. If applicable, they also inquired whether the illustration could motivate participants to address the given health concern. The results of these three studies are specified below.

Semantically consistent colors were shown to facilitate understanding. Stoplight colors (i.e. green, yellow, and red) were universally well-understood in value-judgements [3]. A note from section 2.2 is to nevertheless avoid this combination in order to accommodate those with deuteranopia. Happy and sad faces were also found effective in conveying value judgements, and may serve as an alternative. *Blue was found to be a suitable color for depression*, and red for general anxiousness. **Comparisons** that incorporated an analogy into an understandable and relatable context and used to annotate (numerical) categories were frequently favored. Illustrations and imagery that **contained people** and were **familiar** were also consistently preferred over those that only contained only objects. For instance, for two illustrations conveying the message of "dementia patient gets lost traveling to new locations", a person and a sign was preferred over just a sign. These are shown in figure 2.8, along with other successful and less successful infographics from the studies. Infographics that depicted a **subjective experience** were also consistently favoured over ones that utilized abstract metaphors.

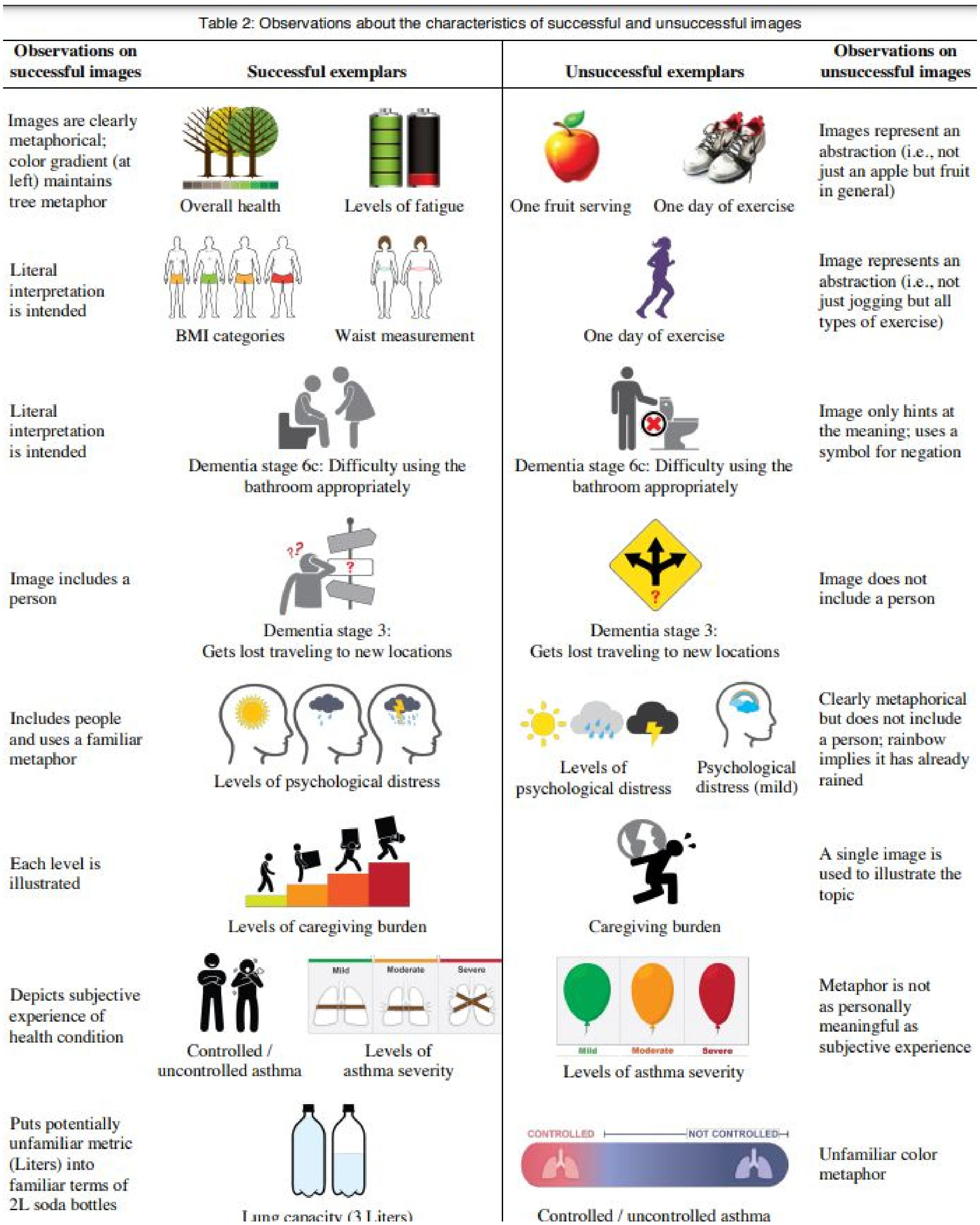


Table 2: Observations about the characteristics of successful and unsuccessful images

Observations on successful images	Successful exemplars	Unsuccessful exemplars	Observations on unsuccessful images
Images are clearly metaphorical; color gradient (at left) maintains tree metaphor	Overall health; Levels of fatigue	One fruit serving; One day of exercise	Images represent an abstraction (i.e., not just an apple but fruit in general)
Literal interpretation is intended	BMI categories; Waist measurement	One day of exercise	Image represents an abstraction (i.e., not just jogging but all types of exercise)
Literal interpretation is intended	Dementia stage 6c: Difficulty using the bathroom appropriately	Dementia stage 6c: Difficulty using the bathroom appropriately	Image only hints at the meaning; uses a symbol for negation
Image includes a person	Dementia stage 3: Gets lost traveling to new locations	Dementia stage 3: Gets lost traveling to new locations	Image does not include a person
Includes people and uses a familiar metaphor	Levels of psychological distress	Levels of psychological distress; Psychological distress (mild)	Clearly metaphorical but does not include a person; rainbow implies it has already rained
Each level is illustrated	Levels of caregiving burden	Caregiving burden	A single image is used to illustrate the topic
Depicts subjective experience of health condition	Controlled / uncontrolled asthma; Levels of asthma severity	Levels of asthma severity	Metaphor is not as personally meaningful as subjective experience
Puts potentially unfamiliar metric (Liters) into familiar terms of 2L soda bottles	Lung capacity (3 Liters)	Controlled / uncontrolled asthma	Unfamiliar color metaphor

Figure 2.8: Successful and unsuccessful infographics with an accompanying explanation. Figure created and borrowed from Arcia [1]; ©2019 Creative Commons Attribution 4.0 International License.

2.5.1 Characteristics of successful and unsuccessful infographics

It was discovered that the groups' inclinations towards certain illustrations did not significantly differ across health varying degrees of health literacy[3]. The most prominent feature of low health literacy participants were their tendency to interpret graphics in a ***"rigidly literal fashion"*** [1]. Often, these were literal interpretations of objects that were abstracted to represent a greater category of things (e.g. someone jogging/sneakers representing exercise, or apples representing fruits). During sessions, these were comments from participants *"It shows.. certain items that you should wear for exercise", "He has four pairs* (.. of sneakers) *and the other one has three"*[3], and *"so many apples!"*[1]. An exception was universally known **metaphors that were evidently symbolic in nature**; these were understood and well-received. This included batteries as a symbol for energy level, stars for a rated measure, and *weather displayed inside a persons head for mental state*.

Arcia et al. recommends removing **distracting or irrelevant features** in illustrations, and linking graphics with **plain-language text** [1]. They also state that it important to take into account the culturally distinct meanings of colors when designing visualizations for a target audience. Abstract concepts such as "time" and "a specialist" were found to be hard to depict in a way that was understood. After the sessions, it was noted that low health literacy individuals did not seem to have a diminished desire to see health information, but rather difficulty in interpreting it [3]. Arcia et al. concludes that successful graphics are characterized by being information dense, lacking ambiguity, and are meaningful even if interpreted in a purely literal manner.

2.5.2 Graphs

Numeric health data are often represented through *graphs*. Turchioe et al. presents a paper where 39 publications with patient-facing visualizations were examined (Arcia et al.'s earliest, inter alia) by three independent reviewers [49]. Their goal was to identify visualization types and components, and research findings connected to the evaluation of these. Reported motivations for research range from testing of feasibility and/or comprehension, user-centered design sessions, and usability testing.

Initial screening identified up a total of 2362 papers on visualization, 834 of which were excluded because they were meant for *researchers or healthcare professionals*. They partition reviewed visualizations into the following categories: line graphs (35%), number lines (25%), bar graphs (16%), icons (12%), scatterplots (4%), body maps (4%), radar graphs (2%), and visual paragraphs (2%). Eighty-eight percent of the visualized data was numeric. Colors were included in seventy-seven of the visualizations, most of which *stop-light colors*. Labels and annotations were included in about half. Several observations are presented from this analysis.

Line graphs make up the majority of patient visualization graphs found in these papers, and are most often used to represent longitudinal and numeric data. Despite this, it was found that participants in several of the experiments provided had trouble understanding line graphs. **Bar charts and number lines were shown to be especially effective** in displaying numeric data in a way that it was understood. In recent years, line graphs have been more prevalent while bar graphs have become less frequent. **Color-partitioning in graphs** were demonstrated to boost participants' perceptions of comprehension. More importantly, they were effective in symbolizing to participants when values reached high risk levels. The authors draw attention to the fact that expressed confidence in comprehension did not always match actual comprehension. Patients generally expressed fondness of visualizations because they made it easier for them to express particular health concerns, discover patterns over time, and have more meaningful clinical interactions.

Turchioe et al. address some problematic aspects with these publications. Methodologies, measurements, and assessment differed significantly between research, indicating lack of standardized approaches. Few articles measured health literacy, graph literacy, or numeracy. Patient characteristics were scarce across articles (often only stating name and age), and mostly consisted of caucasian, middle-aged women with higher education. Due to this and other reasons, the authors ultimately argue that more research on patient-facing visualization is needed.

2.6 Visual communication of biomedical illustrations

Illustrations can be helpful in portraying complex concepts and advanced dynamics of biomedical processes. Actual representations of these are often infeasible, unfit, or not very helpful to display in the way that they naturally occur. A qualitative study by Garrsion et al. found that professionals and non-experts have similar preferences of how biomedical processes are visualized [17]. This section will summarize this research as it highlights some key insights valuable to the medical visualizations created for this thesis.

Sets of illustrations for five biomedical processes were created, namely for signal transduction, constitutive activation, blood flow, aneurysm, and metastasis. Two dimensions of abstraction were applied for each biomedical process - *model abstraction* and *visual abstraction*. Model abstraction expresses how closely an illustration resembles a mental model. That is, a visual construct based on the knowledge of the details and functioning of some phenomenon. The degree of visual simplification of this model denotes the visual abstraction. The illustrations on abstraction space and assets for metastasis are included to demonstrate these abstraction levels, and are shown in figure 2.9. High levels of abstraction results in a less realistic-looking graphic with less visual clutter not relevant to the topic; low levels produce illustrations that are more accurate to nature, detailed, and less narrowly focused.

In their evaluation, participants were separated into two groups, experts and non-experts. Participants were asked to rank the visualizations in each category from top to bottom based on their preferences.

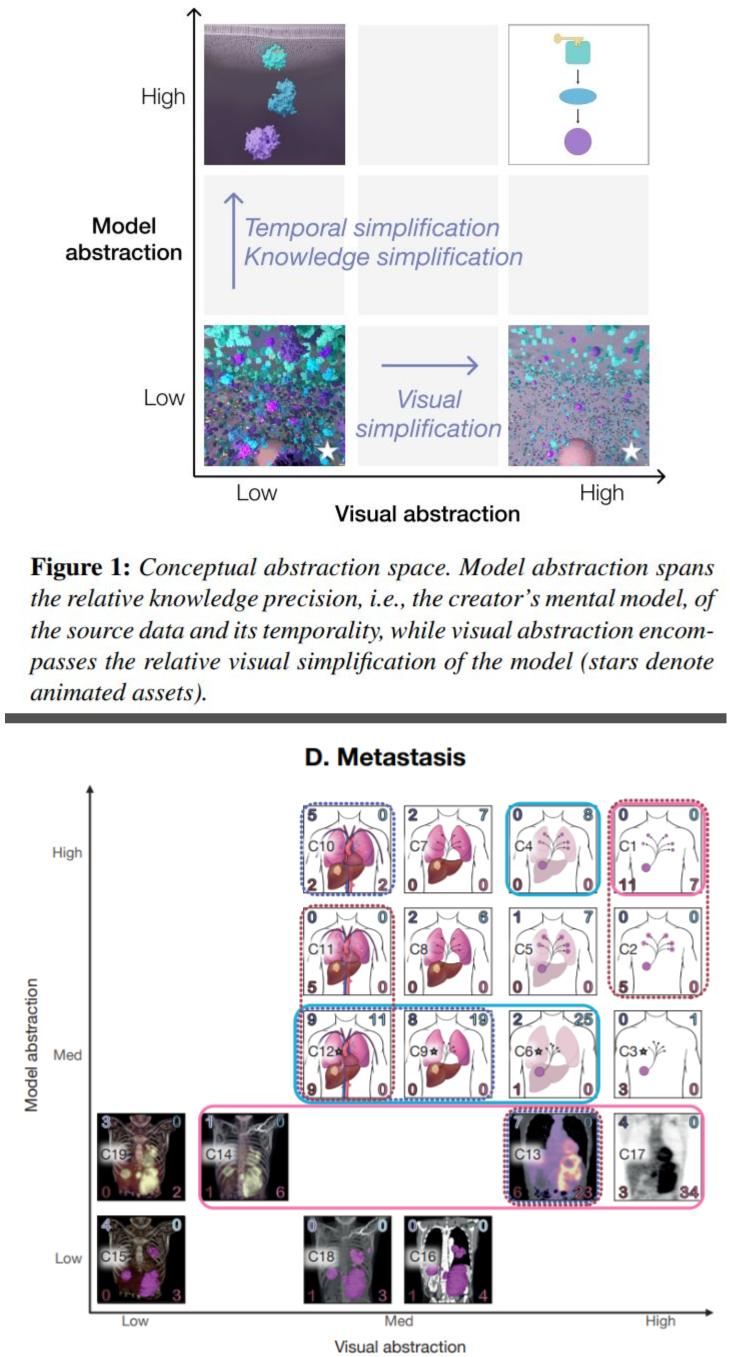


Figure 2.9: The upper figure illustrates the abstraction space. The lower figure show the assets created to illustrate metastasis, and their corresponding levels of visual and model abstraction. Figures borrowed from Garrison et al. with permission [17].

No pronounced preference in combination of abstraction levels were found; however some patterns did emerge. The **most favoured illustrations of participants were often in the midrange of either or both of the abstraction axes**. The **poles of either axes were avoided** with some exceptions. Top preferences were similar for experts and non-experts in all the biomedical illustrations presented. The bottom-rated illustrations were also frequently coinciding, however not as often as top preferences. **Non-experts tended to prefer a slightly higher abstraction space** compared to experts; very realistic assets were by some non-experts described as scary.

Part of the research entailed collecting keywords and comments describing the participants' top and bottom characteristics for all illustrations. The top choices of keywords were similar in both groups. The differences in the bottom choices were more pronounced. On average, both groups chose the phrases **informative**, **easy to read**, and **clear** as their top choices. Experts most often had "informative" as their top choice whereas non-experts tended to choose "easy to read". Both groups had **confusing** as their least desired characteristic. Experts had "simplistic" and "pretty" as their bottom second and third choice; non-experts listed "distracting" and "excessive". An observation to these results is that the preference for a higher abstraction level are consistent with an aversion for distracting and excessive illustrations in non-experts, and vice versa for experts.

2.7 Literary comprehension

Data visualizations for non-experts are often accompanied by worded explanations of whatever phenomena it is illustrating. Some fallacies to language comprehension can increase cognitive load and cause misunderstandings, thus it is helpful to be aware of them. Research on these fallacies is conducted by Matlin, and summarized in her book Cognitive Psychology [32, p. 304-306].

Four linguistic factors that negatively influence literary comprehension are highlighted. Matlin provides various example sentences; several of these stem from linguistic experiments. Others are titles from news articles that her and her colleagues have come across. *These sample sentences are reused for illustration here.*

First, humans have difficulties processing sentences with negation and wording with negative connotation. Consider the sentence *"Few people strongly deny that the world is not flat"*, as opposed to *"Many people believe the world is round"*. Second, passive sentences are harder to comprehend than active ones. Consider the sentence *"The dog was bitten by the man"*, versus *"the man bit the dog"*. Third, she states that overly complex syntax can undermine comprehension and lead to memory overload. Provided is a meta-example: *Reading nested sentences with embedded clauses, such as the one right here, typically requires greater cognitive effort than reading simple sentences.* Last, ambiguity often results in confusion. Matlin presented these news line headings as examples: *"Kids make nutricious snacks"*, *"Miners refuse to work after death"*, and *"Squad helps dog bite victims"*. Whilst being mildly entertaining, these serve as examples of pitfalls to avoid when presenting written explanations of medical information. Arcia et al. also emphasize the benefits of purposefully reducing the volume and complexity of text [3]. The explanations written for the sake of this project are found in Appendix (A).

Chapter 3

Methodology

This chapter presents the research process and design choices for the work presented in Chapter 4. Four sections explain the formation of the project, research phase, acquisition of data, and the application design along with technology choices.

3.1 Project formation

The initial stage was to formulate ideas for a project. I come from a computer science background with no previous experience with data visualization. Supervisor Noeska, who is an associate professor in data visualization, suggested to meet with one of her colleagues at the Mohn Medical Centre to request collaboration. The collegue in question, Leif Oltedal, is a radiologist who works with research on ECT. This meeting was the starting point of this project.

This meeting began with an introduction and description of respective backgrounds. Then there was an exchange of ideas and discussion of various approaches for a project. Leif was asked whether there were any applications in ECT that could benefit from data visualization. The meeting resulted in the following concept ideas:

- MRI correlates to look at volumetric changes in the brain for researchers.
- Medical visualizations of a brain that receives treatment with ECT. Focus on researchers or patients; if the latter, visualizations that were non-threatening and explanatory.
  - Simulaton of electrical current.
  - Images of brain before and after treatment.
- A system that shows ECT-related patient data for clinicians.
- An app or website that displays medical data related to ECT for patients. Specific to each patient or general educational material.
- A system where patients can register adverse symptoms, and have them visualized.

Subsequently, an outline for the project was created. Emphasis on the novelty of research as well as the project's viability in terms of time restrictions, practical issues like technical knowledge acquisition and access to data. The following decisions were made:

Focus on non-experts. Like mentioned in Chapter 1, there are substantially fewer medical data visualizations created for patients than for medical experts. This area of research therefore holds more opportunities for new insight.

Focus on general aspects of the treatment rather than patient-specific data. Due to potential practical challenges in receiving anonymous patient data (given the thesis time span of 8 months), a decision was made to focus on educational content.

A website rather than an app. I had no prior knowledge in app development, but were relatively fluent in the basics of web development. Therefore, it was reasoned that learning a new JavaScript library or framework would be less time consuming than learning a new branch of software development. This would leave more time for learning visualization concepts and focus on theory rather than practical challenges.

Use narrative visualization to provide context for medical information. Patients who are depressed are more likely to have shorter attention spans and a lower drive to learn new things. Format of presented information should be engaging and easy to understand.

An initial project outline was developed as a result of this review: ***A website with information about ECT for patients and others that might be interested, using narrative medical visualization techniques.*** Concrete research questions were later formed.

3.2 Research

The second stage of the research process was to gain insight from *relevant scientific literature, technology,* and *existing solutions*. Data describing the procedure, as well as data used for simulations, were identified during the next stage. This research layed the foundation of the application design choices that were made.

3.2.1 Scientific literature search

Google Scholar, PubMed, and IEEE were primarily used to identify relevant research papers. Supervisors Noeska and Leif both recommended papers to read; for the most part on visualization and ECT, respectively. Keywords such as ″narrative medical visualization″, ″narrative literature″, ″narrative technology″, ″medical visualization″, ″data visualization″, ″color maps″, ″icons″, ″isotype″, ″Electroconvulsive therapy″, ″ECT″, ″ECT qualitative″, ″ECT experiences″, ″graph medicine″, ″graph comprehension″, ″visualization comprehension″, ″visualization non-expert″, ″infographics health″, ″health literacy″, ″low health literacy″, and variations of these keywords were used when searching for relevant literature. There are quite a few publications connected to Helse Bergen about ECT. The national Norwegian guidelines for ECT from 2017 proved valuable. The MMIV website also links to some relevant articles.

Curriculum I have from previous studies in psychology were also used: Ones that write about autonomy, cognitive fallacies, medical imaging, ECT, and concepts relevant to data visualization such as gestalt principles. A book named ″Biomedical informatics″ from a health informatics course at the Western Norway University of Applied Sciences contained information about shared decision making.

3.2.2 Software, frameworks, and libraries

A study of potential technologies to be employed in the project was conducted. This included software for data visualization of medical scans, 3D rendering in browsers, graph visualizations, and front-end frameworks for development. Listed below is a short description of the ones that stood out as most relevant.

Freesurfer and *3D Slicer* are programs used by data visualization and radiology researchers to view neuroimaging data in 2D and 3D. *MATLAB* is a programming and numeric computing platform that is commonly used in data analysis due to its support for a wide range of data representations. It allows a user to code very customized data visualizations and has support for the creation of area plots, line plots, scatter plots, 3D visualizations, and great variety of data constructs. To visualize graphs there is a wide variety of open-license JavaScript libraries that can be used, such as *Chart.js*, *Recharts*, *visx*, and *D3*. For 3D in-browser visualizations, *Three.js* and *WebGL* are both viable options. *Canva* is an online design tool for graphics where highly customized graphs can be created.

3.2.3 Existing solutions

Narrative websites often referred to as *Scrollytell websites*[38] are becoming increasingly popular amongst newspapers and other digital publication forums. Examining a wide variety of data stories were part of the research process. The Pudding [1] offer a multitude of creative and visual data essays about selected topics, such as women pocket sizes, rapper vocabularies, the anti-vaccine movement, and the world population visualized. Some of these are visualized in figure 3.1.

[1] The Pudding website.

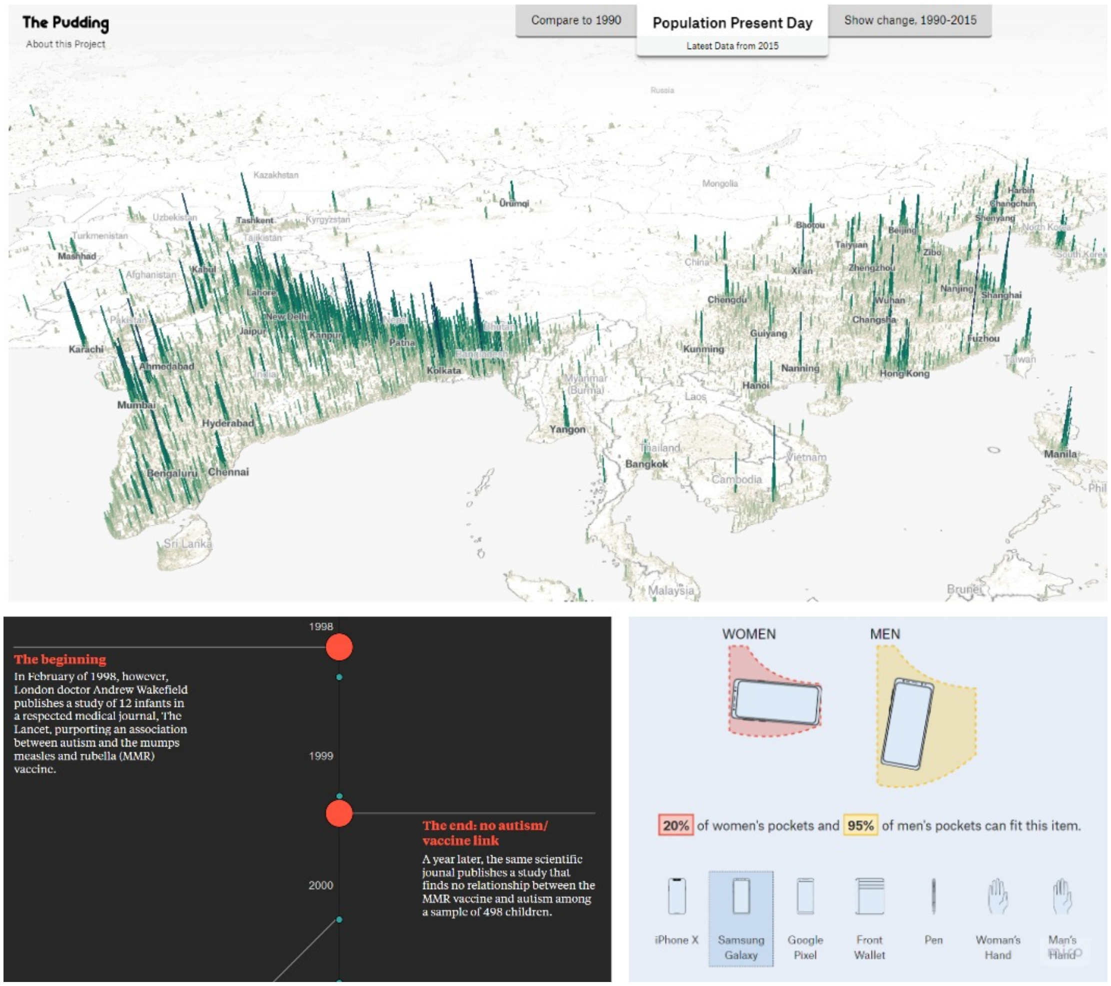


Figure 3.1: Data essays published at The Pudding. Top image: The world population visualized on an interactive map. Bottom right: Scrollytell timeline of the anti-vaccine movement. Bottom left: Interactive comparison between womens' and mens' pocket sizes. Credit: The Pudding.

3.3 Data acquisition

Relevant data for visualization was identified during this stage. According to the American Nurses Association there are three types of data that together form a foundation for patient information. Domain-specific data such as relevant literature or national guidelines about a condition or treatment. Agency-specific data specific to the organization providing care, such as current policies, routines and procedures. Lastly, there is patient-specific data acquired from the electronic health journal or other sources.

These were the data needed for the project:

- An MRI-scan to be used for visual simulations of medical data.
- Domain-specific and agency-specific data about ECT.
- Explanatory images for the website.

3.3.1 Medical visualizations

To simulate data associated with the head and brain an MRI-scan was needed. Main supervisor, Noeska, originally offered the her personal MRI-scan to be used for simulations in the project. This was initially used to get familiarized visualization software. Imaging artifacts due to metal braces made this particular scan problematic to use for 3D rendering. Instead, with permission from the author of ROAST, one of the sample MRI-scans from there used for the final visualizations. In the graphics presented in this thesis, the face of the person in the MRI-scan has been modified with the online image-editing software Photopea to protect the subject's identity.

3.3.2 Domain and agency-specific data

Domain specific data such as electrode placements and procedure details, and agency-specific data such as the protocols for ECT at Haukeland University Hospital were identified during this stage. This information was discovered through literature and communication with the ECT section at the hospital.

I identified information aspects related to ECT through literature and contact with the ECT section at Haukeland University Hospital. Treatment indications are covered in papers/literature. Statistics were initially gathered from scientific studies, Sweden's national ECT quality register, and a brochure about ECT given to patients at Haukeland (with data from the Haukelands local quality register). The statistics that ultimately were used in the illustrations both stem from the ECT section at Haukeland. The effects from the brochure, and adverse effects from the paper cited[24]. During a visit to the ECT section at Haukeland, I recorded a sound recording was from one of the doctors who perform the procedure. They explained various aspects of the treatment course. An example output from the EEG, EKG, and EMG recordings during a seizure were shown during a visit to the ECT section.

3.4 Application design

The fourth stage involved creating and deciding on an application design. It was an iterative process of trial and error that involved exploring strategies for displaying the identified data. Ideas were created, researched, and often subsequently scrapped. Ultimately, a pool of potential suggestions remained. This section contains the design decisions that were made.

3.4.1 Choice of technology

React is a library in JavaScript used to build user interfaces (UIs), and was chosen as the main programming feature of this project. The primary reason for this is because of its declarative qualities, a software concept written about in Chapter 2. React makes it easy to construct reusable components that can be easily customized. It therefore becomes easy to build a website architecture that is scalable and coherent; especially for this project it was well-suited for building dynamic content with different post types. The library is widely used in modern web development, and therefore has a large online community that can provide help with different problems. The functioning of React is described in more detail when explaining the website implementation (4.3.1).

Two softwares were used to create the medical visualizations. A MATLAB tool called ROAST, abbreviated from the name ”Realistic, vOlumetric Approach to Simulate Transcranial electric stimulation” was used [23]. This was a gathered from the master thesis of Ingrid Mossige[36], who is an University of Bergen alumni. The other was *3D Slicer*, a visualization program used by data visualization and radiology researchers to view medical scans in 2D and 3D. From here on it will be referred to as Slicer. This was chosen as it was intuitive and relatively easy to understand without prior knowledge. Another reason was that, compared to choosing Freesurfer, it was a much less demanding installation process and there was no need to isolate certain parts of the scans.

3.4.2 Interactivity

Scrolling was deliberately chosen to be the site's main method of interaction. The primary reason to this is the the comparatively high average age of ECT patients. We did not wish to let potential lack of fluency in technology impair user experience by keeping the mechanism of interaction relatively simple, although several narrative patterns were viable alternatives to a linear path

(2.3). A choice to exclude interactive 3D visualizations was made on the same grounds. Due to the sequential nature of scrolling, i.e. either up or down, it was also deemed well-suited for telling the patient narrative. Programmatic improvements to the scrolling experience with narrative transitions of graphics and text were consequently made a focus.

To minimize interaction cost, and relieve the need for continuous scrolling, some click-based functionality was desired. As mentioned in the project background in Chapter 1 (1.2.2) there was a Norwegian qualitative study on patient experiences with ECT. Part of the feedback gathered in this involved patients that desired to hear user experiences about the treatment from other patients. A **testimonies page** with images and quotes containing anonymized patient experiences was included to be an exploratory feature of the website.

3.4.3 Visual platform

Sketching out concepts and designs was done in Figma and Miro. The visual platform was designed in a neutral dark blue tone with contrasting white text. Orange was utilized to create **visual salience** and draw attention to specific elements of importance. The combination orange and blue is also acknowledged to be a safe choice with regard to those with **color-vision deficits**. These terms are explained in the previous chapter (2.3 2.2). Conveniently, these colors coincide (or are at least similar) to those used at Helse Bergen.

Chapter 4

Results

The following chapter presents the material produced for this project. It begins by outlining the steps involved in creating the medical, statistical, and other illustratory visualizations. Then, it proceeds to explain the implementation process of the website. Lastly, a metadescription of the written content on the website is given. In chapter 3, *Data aquisition*, it is explained how much of the data shown in this chapter was obtained.

4.1 Medical imaging-based visualizations

The medical imaging-based visualizations were made by simulating transcranial electric stimulation (TES). For simplicity, these visualizations will from here on just be known as *medical visualizations*. I produced 2D and 3D images and animations that the show electric field in the brain with a temporoparietal right unilateral electrode placement. Some show only the placement of electrodes. The simulations were created with ROAST[1], an open-source program

[1]ROAST (version 3.0, codename Hell's Kitchen). Github repository.

written and executed in MATLAB [2]. Some of the visualizations were made in 3D Slicer [3], a software package broadly used for scientific imaging research that was extensively used throughout the project. Different display methods and alterations to the simulations were done to produce the material presented here. This section explains this process.

4.1.1 Fundamentals

ROAST automates each step of the simulation process, according to Huang et al.[23] and the ROAST documentation[4]. They state that it operates sequentially by segmenting the head, positioning out virtual electrodes, generating a finite element method mesh, and solves for electric field distribution and voltage. The simulations are based on an MRI-scan (in the NIfTI file format which is commonly used for neuroimaging). During the simulation the program logs each step in console and gives indications on what parts of the process went well and pointers if any additional processing should be done to the data prior to a step. The program outputs a log and a multitude of files that each contain some part of the simulation, such as the electrodes, gel, or electric field. To run the simulation again at a later point these intermediate files are used.

4.1.2 Simulation of transcranial electric stimulation

This section describes the preparations and specifications of the simulations produced with ROAST.

Initially, the software was set up. The ROAST repository was cloned using Git, and a student license from the university was used to install MATLAB (R2021B). The documentation of ROAST is lengthy and explain in detail how

[2]MATLAB R2021b (Academic license).
[3]3D Slicer (version 4.11.20210226). Website.
[4]Software documentation Accessed February, 2022.

to set up different parameters for the simulation. An example NIfTI file from the repository was chosen to run the simulations for this project (further described in 3.3.1).

Specifications from Ingrid Mossige's master's thesis[36] were replicated in order to acquire representative patient parameters for electrode location, current, and disk information. Right unilateral electrode (RUL) placement for ECT is most commonly used in Norway. Hence, this placement was chosen for the simulations as it is representative for most patients. In Mossige's thesis, *Volume Increase of the Hippocampus after Electroconvulsive Therapy*, ROAST is used to simulate the electric field in the hippocampi for patients receiving ECT. Mossige includes a table with parameter specifications and command run in MATLAB, and has followed the same method as Argyelan et al. for electrode placement [5, 36]. Listing 4.1 demonstrates the adaption of this command used in our simulation.

```matlab
% Parameters:
% File: NIfTI file, MRI-scan of head
% Electrodes : C2 with 900 mA current, FFT8 with -900 mA current
% Electrode type: Disk
% Electrode size: Radius 25mm, height 1mm
% Zero Padding: 60 slices
% Simulation tag: Label on output files

roast (
    'example/mri.nii',
    {'C2', 900, 'FFT8', -900},
    'capType', '1005',
    'elecSize', [25 1],
    'zeroPadding', 60,
    'simulationTag', 'MossigesParameters'
);
```

Listing 4.1: ROAST command used to simulate TES with right unilateral electrode placement. Electrode specifications calculated by Mossige.

A Thymatron System IV machine is used to administer ECT at Haukeland. Stimulus duration and pulse frequency may vary between subjects, but an electric current of 900 mA is constant for all patients [36]. The electrode placement parameters corresponds to temporoparietal right unilateral electrode placement proposed by D'elia [12]. The 10-05 system of EEG placements illustrates this positioning and can be seen in figure 4.1. Mossige originally used the electrode placement FT8, but changed it to FFT8 to avoid problems that arose with placing this electrode for a lot of subjects [36]. The zero-padding denotes extra space added around the subject in the simulation. Sixty slices are added to avoid that the placement of electrodes exceed the image boundaries.

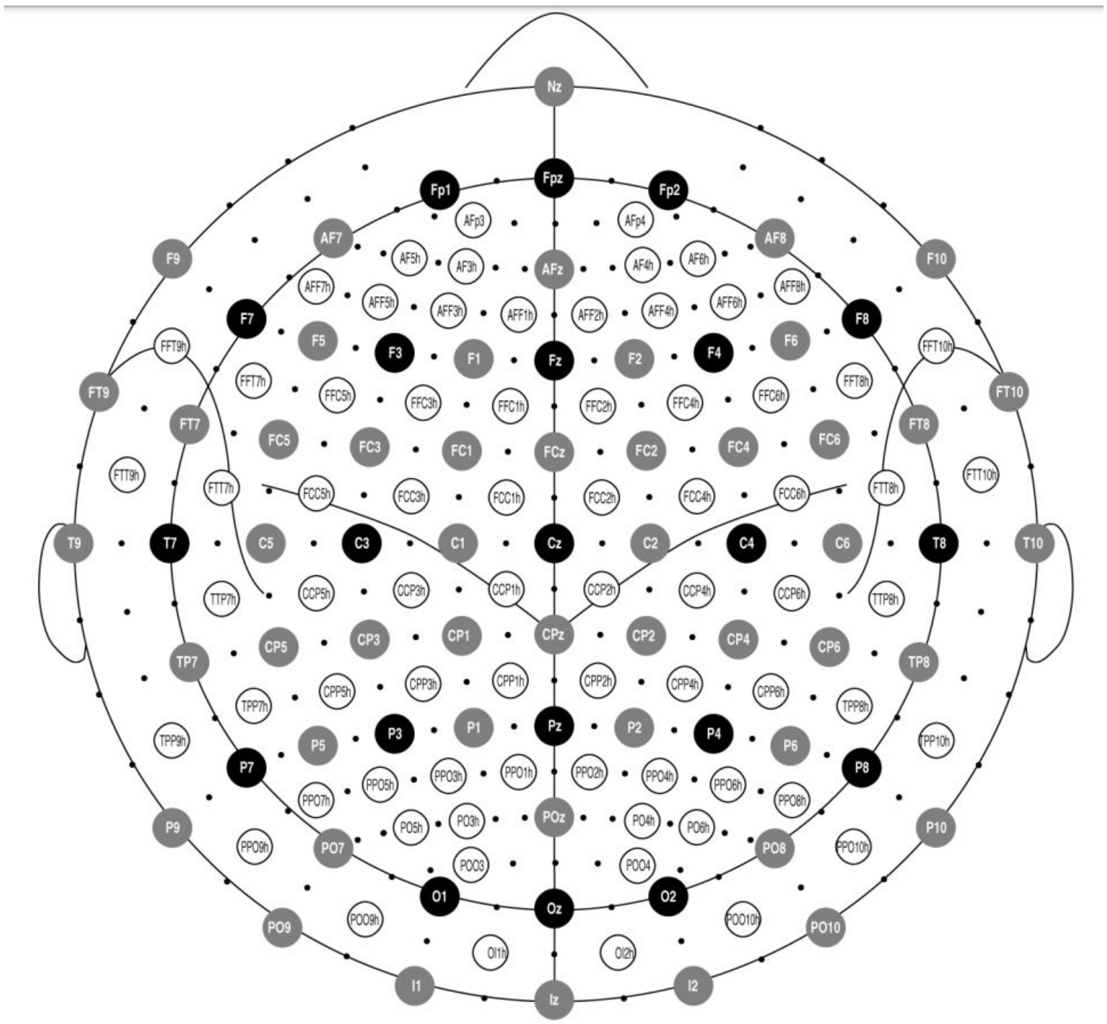


Figure 4.1: The 10-05 EEG system with placement of electrodes. Electrodes are positioned in curves with five percent distance to each other. An extension of the international 10-20 and 10-10 systems. Figure borrowed from Oostenveld and Praamstra with permission [41].

The simulation took about 10 minutes to execute. As a final step, ROAST generates slices of the MRI, the segmentation, voltage, and electric field. It also renders 3D visualizations that show voltage and electric field in simulation of the cortical surface on the brain. This output is exemplified in figure 4.2. All visualizations apart from the MRI slices are rendered with one of MATLAB's predefined rainbow color maps, "jet".

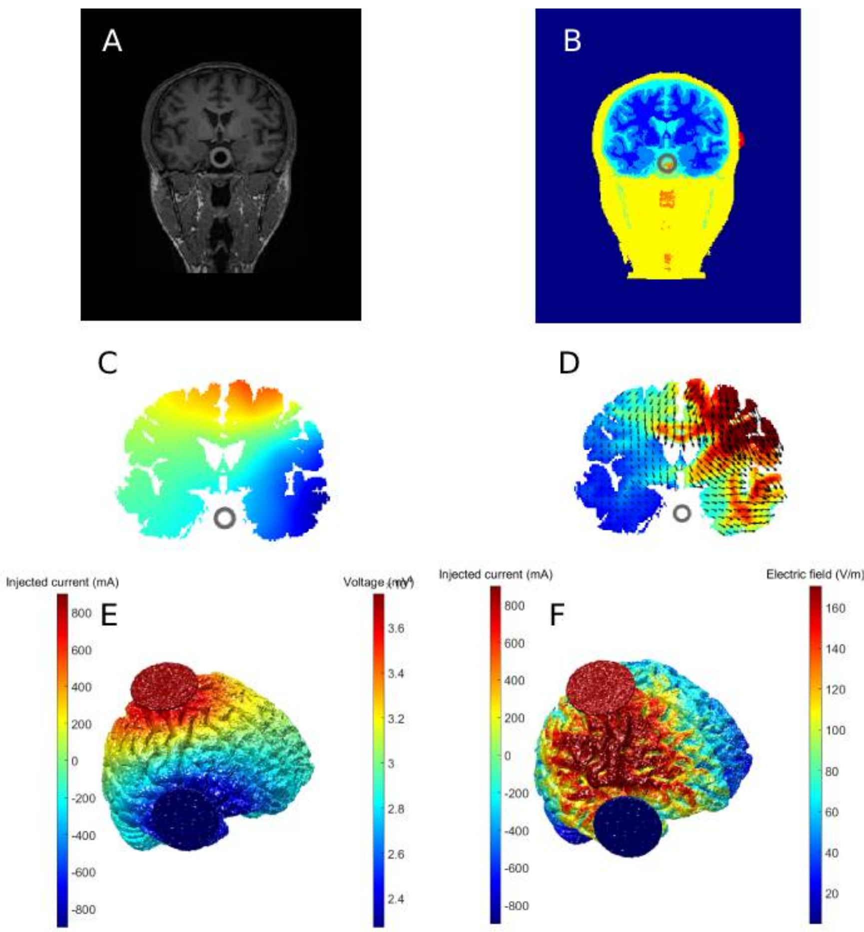


Figure 4.2: The output simulation of ROAST with RUL electrodes, by running the command in listing 4.1. A: MRI. B: Segmentation. C: Electric voltage. D: Electric field with directional arrows. E: 3D rendering of the electric voltage on the cortical surface. F: 3D rendering of the electric field on the cortical surface.

Out of these visualizations, the *electric field distribution* (explained briefly in Appendix A) was the most illustrative for the electric stimulus and electrode placement of ECT treatment. The 3D renderings show the relationship between the placed electrodes and the activity on the cortical surface of the brain. The 2D slice shows the direction and strength of the electric field.

4.1.3 Final visualizations

This subsection presents the final medical visuals and the course of operations used to create them. Part of the 3D visuals were achieved by making local alterations to the code in the ROAST repository. Some of the simulation files were imported and layered in Slicer, and stem from volume rendering there. Most of the images are processed in some way using the free, open-source, image-editing software Photopea.

As mentioned in Chapter 3, *Data acqusition* (3.3.1), the facial features of the subject have been digitally manipulated in this thesis to protect their identity.

Part of the research topic was exploring how different color maps were perceived, and what angles seem relevant. A quest to figure out whether changing the color maps of the simulations were possible were carried out. If possible, two approaches were probable - either to change settings in MATLAB or the code of the ROAST repository itself. It turned out to be the latter, discovered by doing a general keyword search of "colormap" in the files. The search yielded the file "visualizeRes.m"[5], a script rendering the visualizations in MATLAB at the end of the simulation. The code is split into sections for each of the rendered visualization windows. Here, it was possible to change the part of the code responsible for colormap selection to other predefined MATLAB colormaps.

[5]The ROAST repository is licensed under GNU General Public License v3.0 which permit alterations to the file in question. These changes were performed on a private copy during the spring of 2022, and is not redistributed in any way.

A MATLAB add-on named "Perceptually uniform colormaps"[6] contain color maps such as *Viridis*, *Plasma*, *Magma*, and *Inferno*[6]. These were chosen as a result of the preliminary research done on color maps before implementation. The predefined color map *Pink* was included as it somewhat resembles the natural color of the brain. The file "visualizeRes.m" was updated with each of the color maps and the simulation was run again. See figure 4.3 and 4.4 for the results.

[6]"Perceptually uniform colormaps" by Ander Biguri, version 1.3.2.

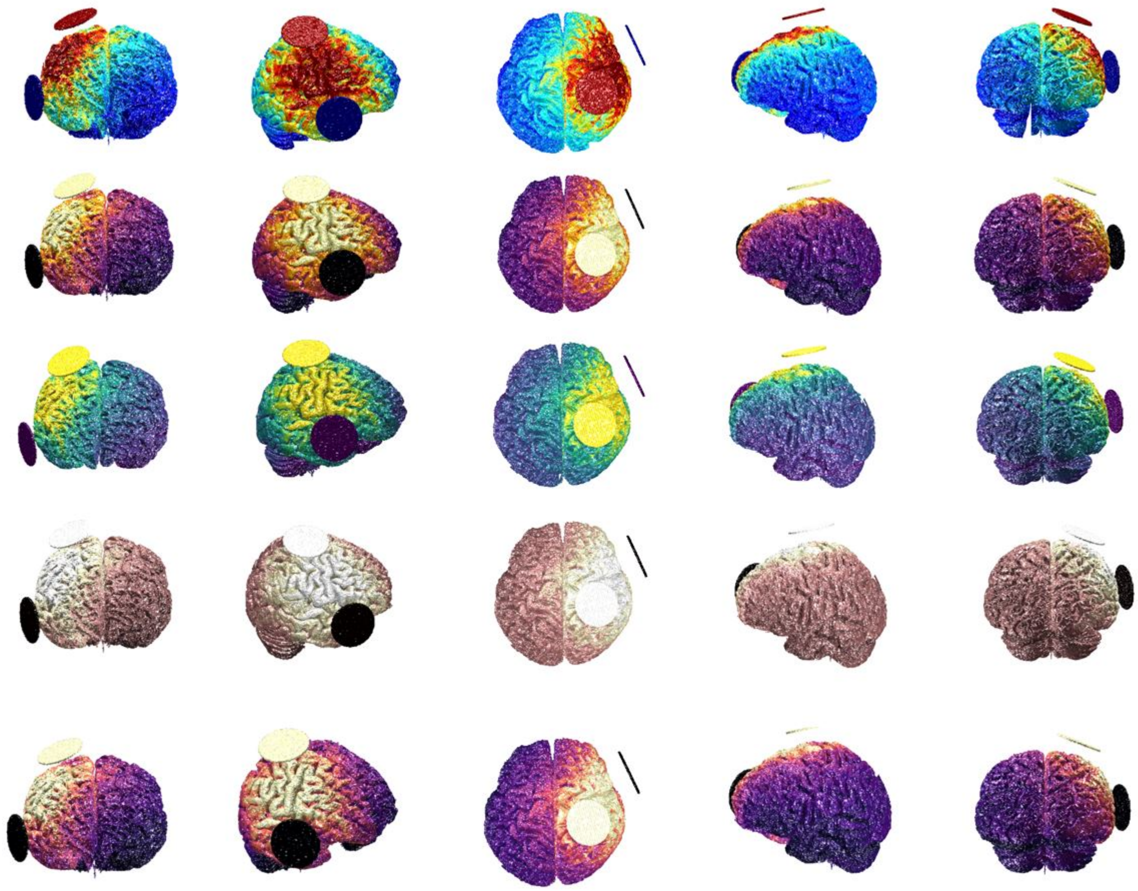


Figure 4.3: A 3D simulation of the electric field on the cortical surface of the brain using right unilateral electrode placement. Color maps from top to bottom: Jet, Inferno, Viridis, Pink, and Magma. Visualization created for this project.

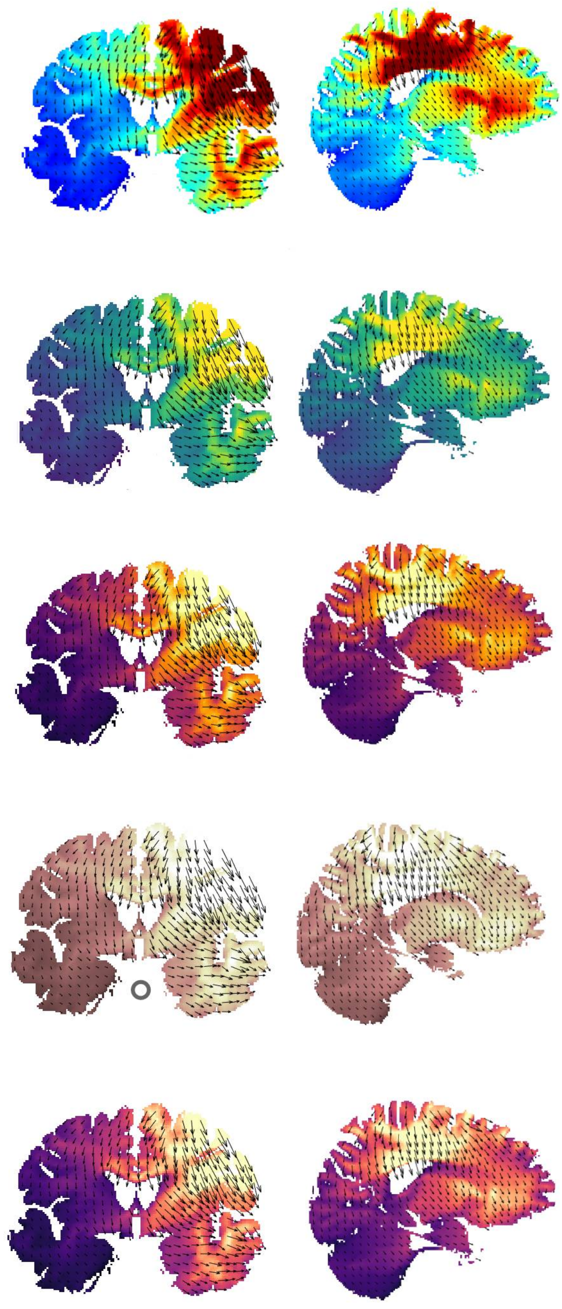


Figure 4.4: Simulation of the electric field on the brain with a right unilateral electrode placement from coronal and sagittal planes. Color maps from top to bottom: Jet, Inferno, Viridis, Pink, and Magma. The images are from slightly different slices which may account for variations in the displayed data. Visualization created for this project.

All the NIfTI files produced by ROAST during the simulation were imported in Slicer. The MRI-scan (mri.nii) and electrodes (.._mask_elec.nii) were layered and volume rendered. The electrodes with the preset *DTI-FA-Brain* and the scan with the preset *MR-MIP*. Adjustments to these volume renderings were made until the electrodes were contrasting and easily visible, and the head vague and bright. This was done to to accentuate the electrodes and make the head neutral and non-disturbing. This was done to create **visual salience**, as written about by Segel and Heer [46] and paraphrased in chapter 2 (2.3).

Two additional versions were created representing different levels of abstraction in electrode placement. One more detailed, and one less detailed. The detailed version was created by tweaking the parameters in Slicer, and thereby showing the electrodes relative position to the brain. The the less detailed version was created in Photopea, and are in part hand drawn. They show the contour of the head, face, and nose. These can be viewed in figure 4.6.

A selection of the electric field slices were layered on top of the corresponding slice from the MRI. In one of them, different opacity levels were set to show the relation between the brain structure and electrical field. Eyes were included to see if this was something which evoked reactions. See figure 4.5.

The visuals in the two previous paragraphs were put side by side to contextualize each other and better explain how the electric field in the brain is related to the placement of electrodes. See figure 4.7.

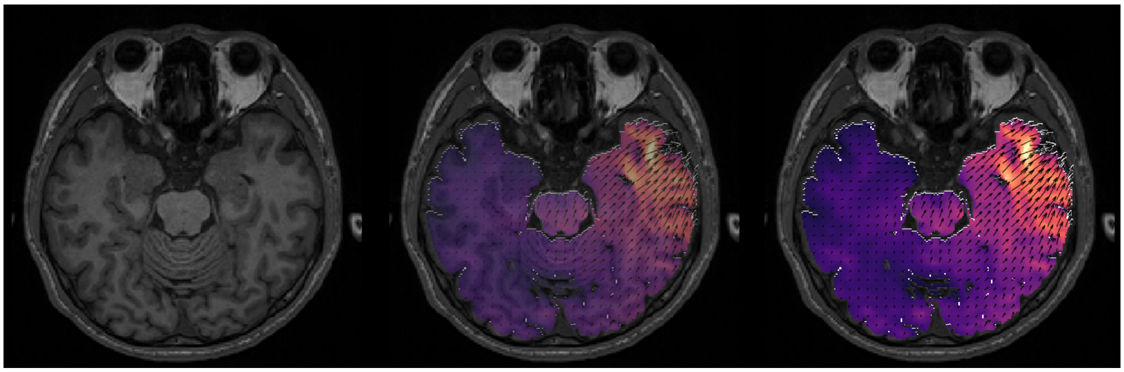


Figure 4.5: Electric field layered on MRI, shown with opacity 0, 0.3 and 1. Visualization created for this project.

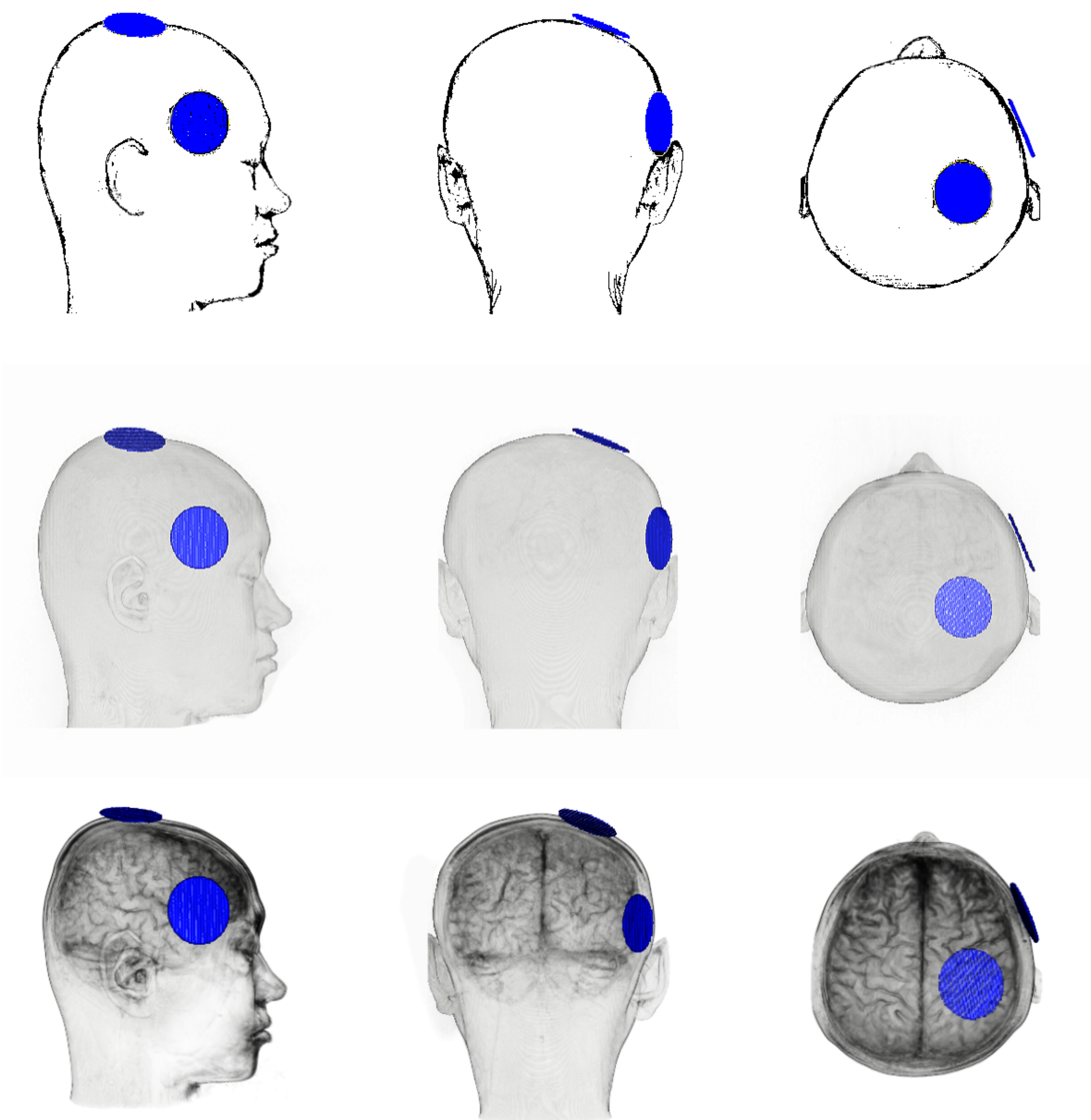


Figure 4.6: Head with temporoparietal right unilateral electrode placement. Three different abstraction levels. Visualization created for this project.

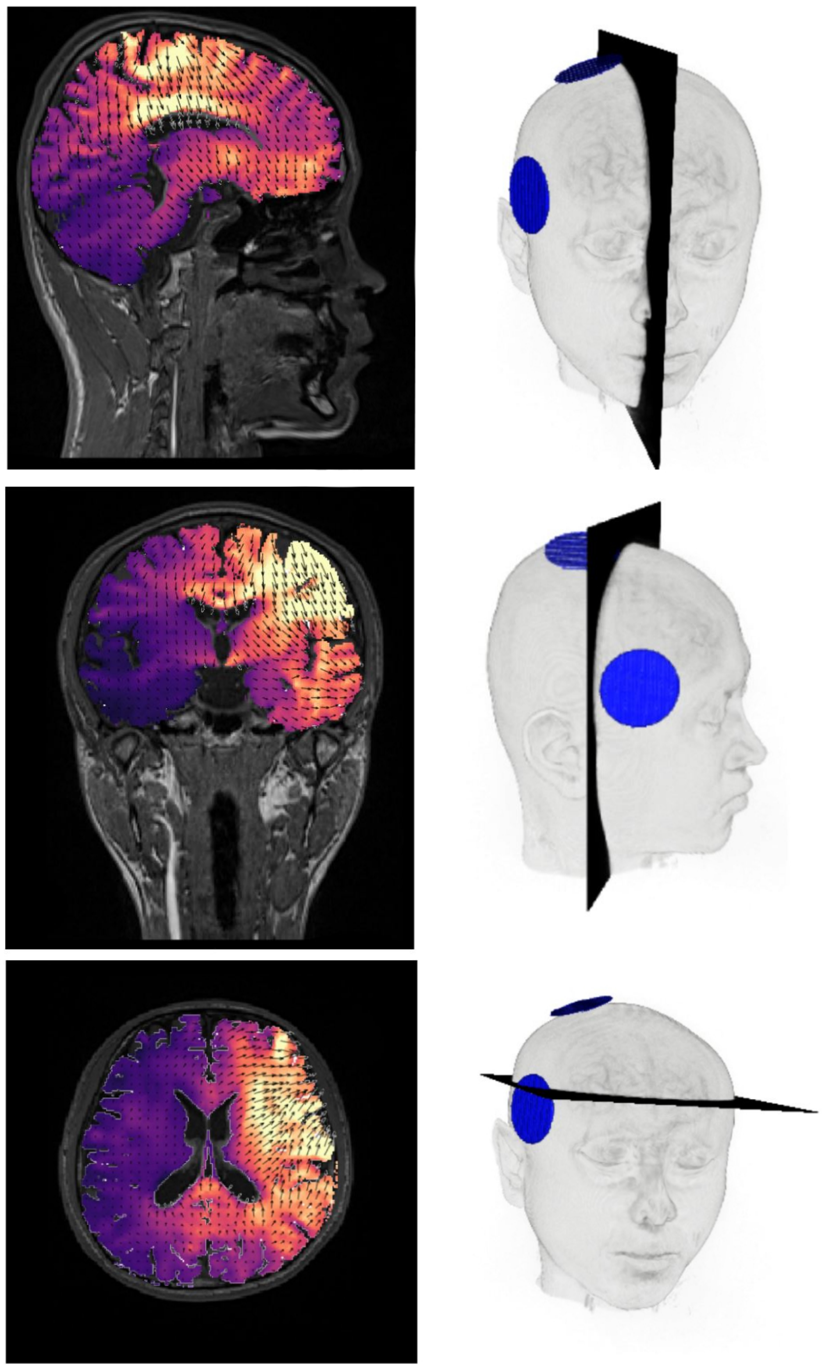


Figure 4.7: Electrical field on MRI slices to the right. Volume rendering of head with slice and electrodes to the left. Visualization created for this project.

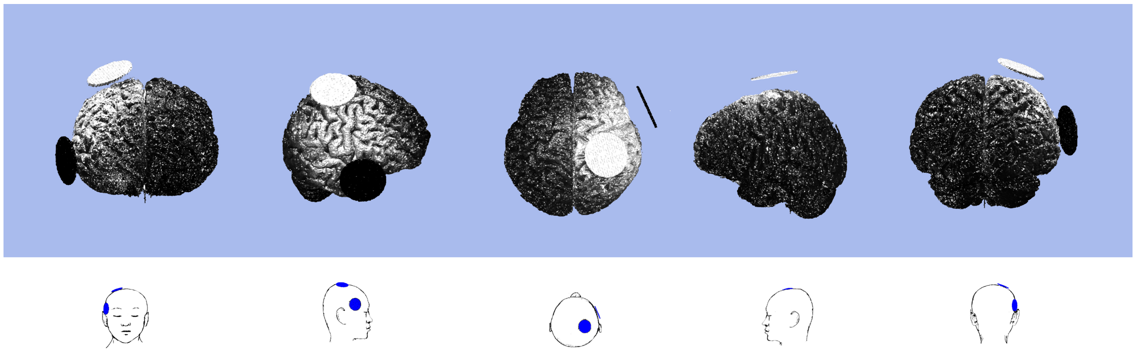


Figure 4.8: Electrical field displayed on cortical surface. Contextual illustrations below. Visualization created for this project.

Contextual images of a head with electrodes were paired with the 3D simulations showing the electric field on the cortical surface. This was done to create **points of comparison** (2.3) for different angles. These are shown in figure 4.8. Several animations of the figures depicted in this section were also created. These include a 360° rotation of the 3D brain simulation, a rocking version of the volume rendering of the head with electrodes, and opacity change on the electric field layered on top of the MRI.

4.2 Graphs and illustrations

All illustrations in this section are created with Canva, an online graphical design platform [7]. Statistics related to the effects and short-term adverse effects related to ECT were visualized through graphs. Basic prototypes of dynamic and coded versions of the same graphs were developed on the website, but were excluded in the final code base and is not covered in this chapter. This was because they were inept at testing the narrative concepts posed in the research questions, such as the use of metaphors, different isotypes, and variations of graphs. This section presents graphs and illustrations.

[7] The subscription used was Canva Pro under free trial.

4.2.1 Graphs

The illustrations were created based on the research performed on visual comprehension of graphs, metaphors, and isotypes (2.5). Specifically, five principles are followed: All illustrations contain **people**, use a **clearly symbolical metaphor** that has been shown to be well-recognized and liked (weather inside a person's head), use **blue** as a color to reflect depression, and picture a **subjective feeling**. Although isotypes are stated to be most useful in graphs when depicted less than 6 times by Haroz [19], this was in included to see if it would be appropriate to demonstrate the relation of how many people improve in contrast to those who do not.

Three graphs show the effects of ECT[8], shown in figure 4.9. Two graphs, seen in figure 4.10, show temporary side effects from treatment. There are both Norwegian and English versions of the graphs.

[8]Correction: There is an official wording for the answer options from Clinical Global Impression Improvement (CGI-I), which are: Very much improved - Much improved - Minimally improved - No change - Minimally worse. The answer options were translated from Norwegian by the author and are technically incorrect. The versions presented here were not corrected as these were the ones evaluated through the survey.

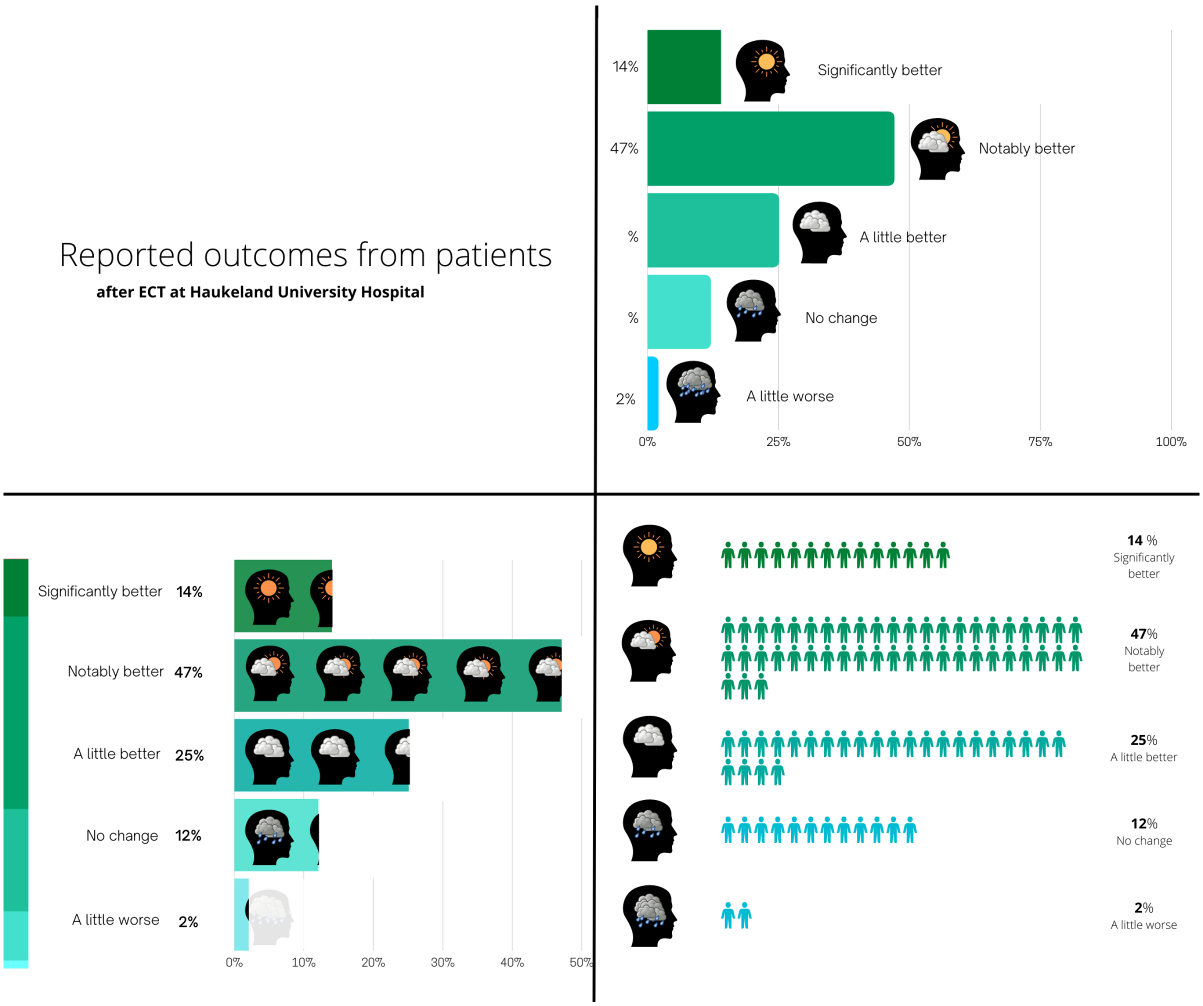


Figure 4.9: Three different graph representations of treatment effect of ECT. See footnote on previous page for official CGI-I wording of answer options. Visualization created for this project.

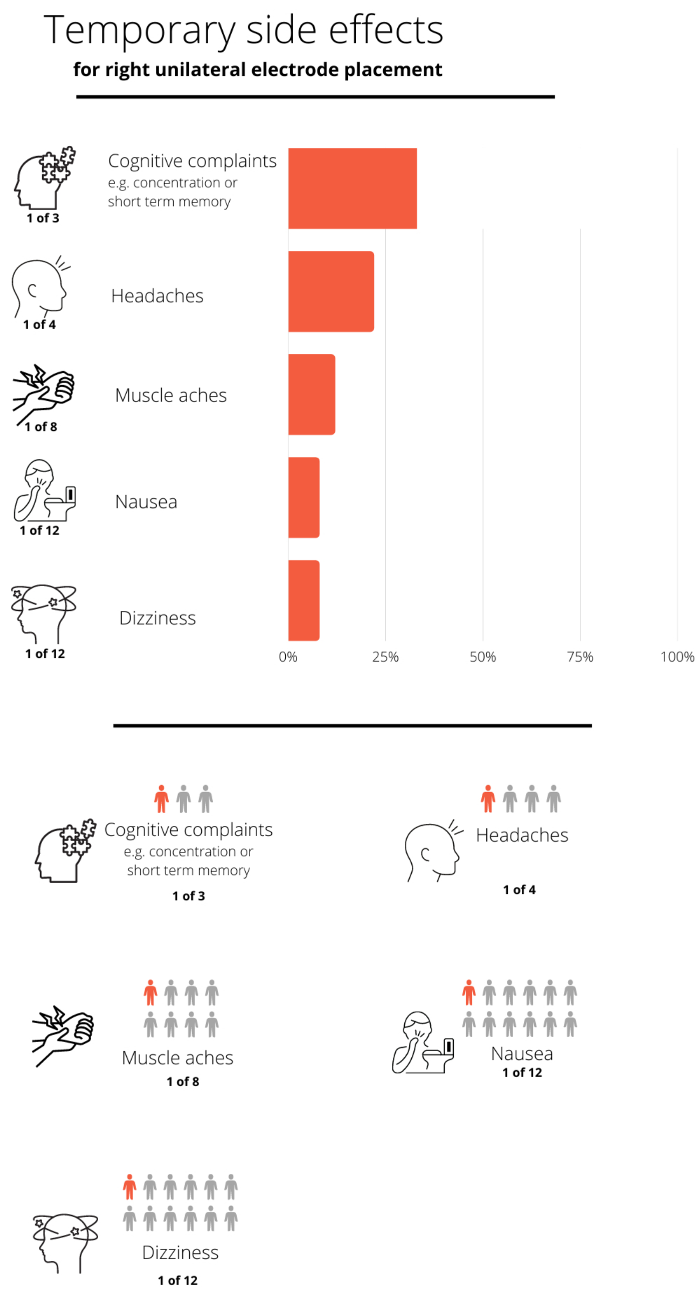


Figure 4.10: Three different graph representations of temporary adverse effects associated with ECT. Visualization created for this project.

4.2.2 Illustrations

Two supplementary illustrations were created. A calendar illustrates the time frame of a standard course of ECT-treatments given at Haukeland University Hospital, seen in figure 4.11. Various ECT-machine recordings are arranged with their corresponding measurement type, depicted in figure 4.12. General opinions, as well as to what extent these would be interpreted literally of figuratively was a matter of interest in the subsequent review.

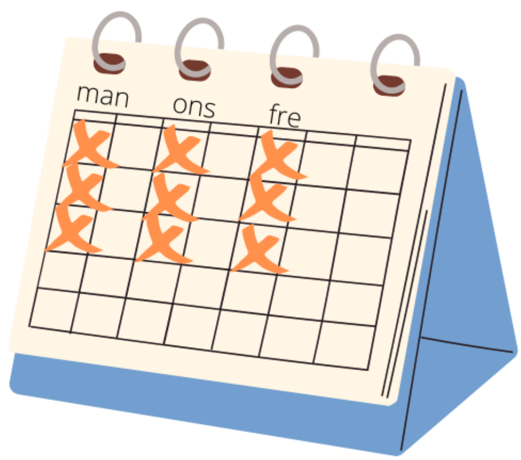


Figure 4.11: Supplementary illustration to descriptive text: Treatment is given three times a week at the the ECT-section at Haukeland - Mondays, Wednesday, and Friday. Illustration created for this project.

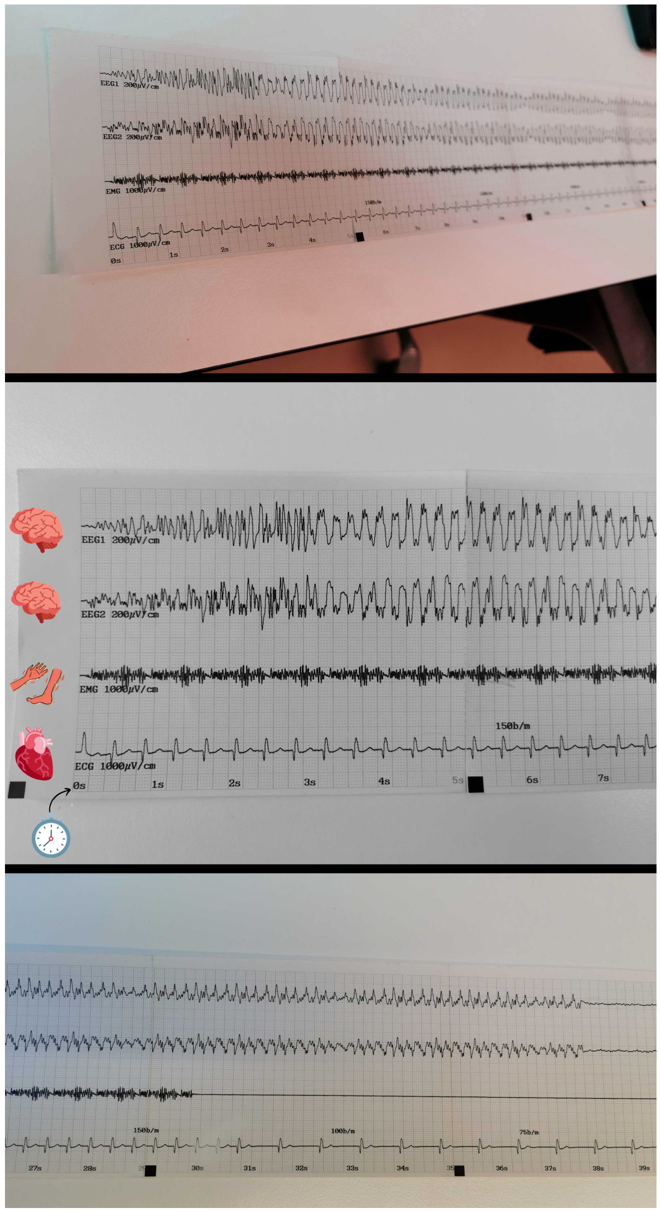


Figure 4.12: During a seizure the ECT-machine records the electric activity in the brain, muscles and heart. Small illustrations have been added to make this easier for patients and others to understand. The brain corresponds to the electroencephalogram (EEG), the extremities to the electromyography (EMG), and the heart to the electrocardiogram (ECG). The clock points to the time duration of the seizure, which is measured in seconds. Visualization created for this project.

4.3 Website implementation

The website was created to place these visuals into an explanatory, interactive and engaging context. The code base only consists of a front-end as it has no advanced dynamic data processing or need to store information. The reason for choosing React and JavaScript to implement the code base is described in Chapter 3 (3.4.1). Much attention has been paid to creating various "post types" that are rendered dynamically. These post types are meant to support different narrative forms.

4.3.1 Fundamentals

Web development can be separated into three divisions: structure and semantics, logic, and styling. The languages traditionally used to define these are HyperText Markup Language (HTML), JavaScript (JS), and Cascading Style Sheets (CSS), respectively [18]. The structure of the website is contained in the DOM; a tree-structured data representation of the elements that compose the website.

Usually, other front-end frameworks transpile their code into one of these three languages. Transpilation means to translate code from one language into valid, but mostly machine-readable, code in another programming language.

React, the library used to create the website for this project, transpiles into JS [9]. The library is reowned for it's functional characteristics; loosely coupled *components* manage logic, semantics, and structure. These components are created as instances with properties and functions, each with their own life cycle, and therefore bear some resemblance to an object in Object-Oriented Programming (OOP). A component can either be defined as a class component or a function component, the latter becoming increasingly popular in recent years. Each

[9]Official React documentation, Copyright © 2022 Meta Platforms, Inc.

component can compose a structure by defining a parent, usually with children elements, in a syntax extension to JavaScript named JavaScript XML (JSX). It is also possible to write React without JSX. The component manages logic and user interaction internally, such as states or events that come with button clicks.

A React component is instantiated as a regular HTML-tag with angle brackets, i.e. <>, in the same way as an image, paragraph or section headline. Once instantiated, the component is rendered as a ”branch” in the DOM. If the element has several children, the parent element is constructed as a ”div” element. See listing 4.2 below.

```
import React from 'react';
import ReactDOM from 'react-dom';

class Hello extends React.Component {
  render() {
    return <h1>Hello, {this.props.name ?? "World!"}</h1>;
  }
}
ReactDOM.render(
  <Hello name="Kafka!" />,
  document.getElementById('app')
);
//Rendered: Hello, Kafka!
```

Listing 4.2: Example of React class component

4.3.2 Architecture

There are six main components that construct the architecture of the website: *Application*, *Header*, *Menu*, *Content*, *Section*, and *Post*. See figure 4.13. Apart from the first, these are all class components.

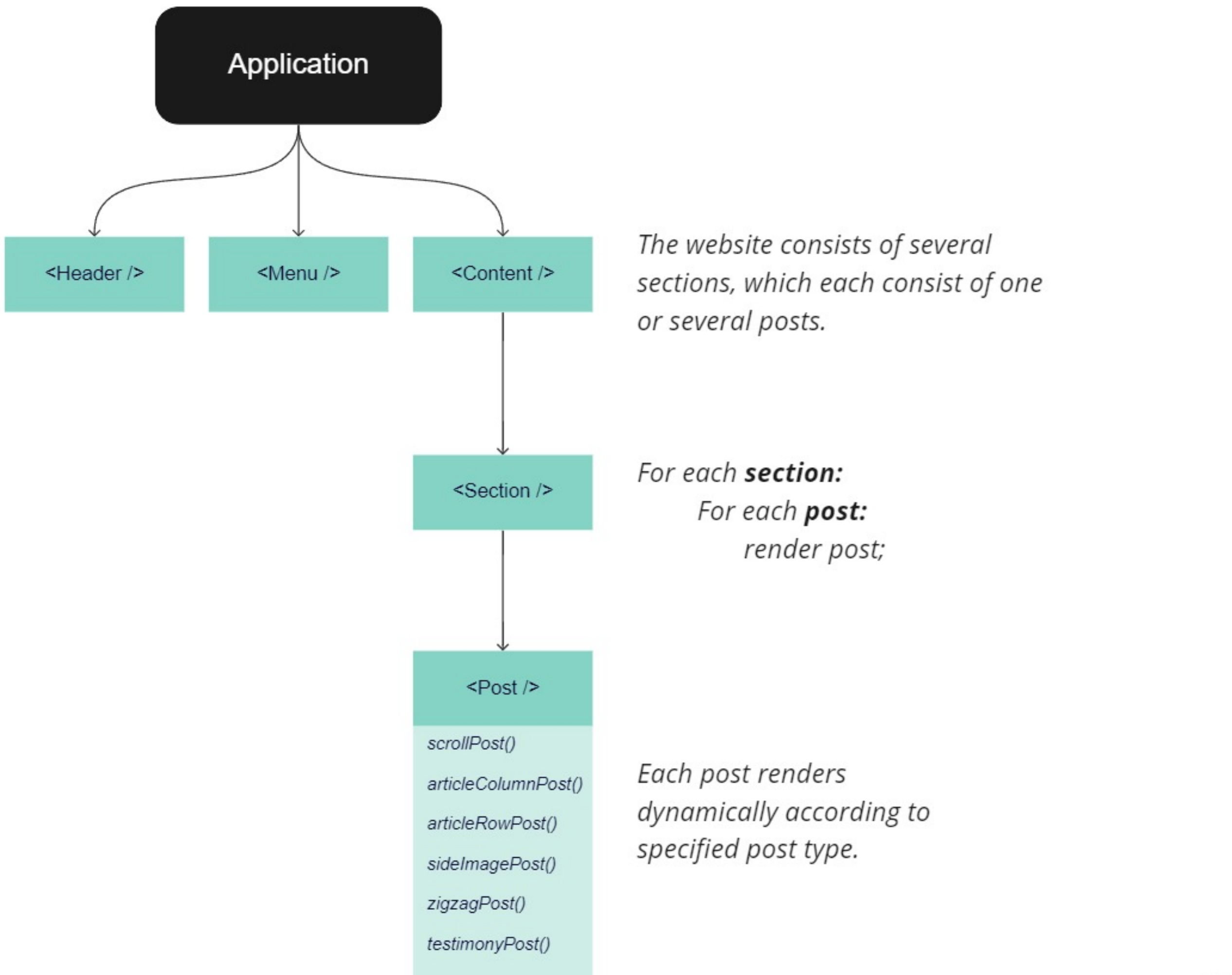


Figure 4.13: Diagram of the React components that compose the primary architecture of the website.

The project contains one more component, *Scrollama*, used to enhance the scrolling user experience. This last component will be explained during description of the *Scroll Post* implementation (4.3.8).

4.3.2.1 Content folder

The project contains a "website content" folder. All content that is shown on the website, such as images, header, and text (section.js files containing posts), reside here. This implies that without modifying any other parts of the code, one may quickly and relatively easily construct a "new web page" by changing the information in this subdirectory. See figure 4.14.

Would there be a future need to implement a back-end to this website (e.g. for database storage), this could be done simply by injecting the required data from the back-end into the files contained in this folder.

Storing all mutable parts of the code in this folder was done intentionally to facilitate cohesion and minimize coupling. It allows the content of the page to be flexible and scalable while the rest of the code remains untouched. An improvement that could be done to this code in these files to set reasonable default values

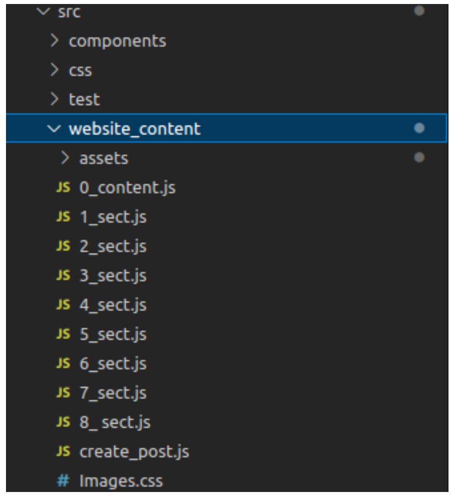


Figure 4.14: Folder with entire content of website.

4.3.3 Styling

Cascading Style Sheets, mentioned above, are used to define the appearance of the elements in the DOM. The project contains three CSS files. App.css contains about 700 lines of code that style the **Header**, **Menu** and different **Post** types; the CSS of the file is grouped logically together by these categories and separated by comments. It is the styling of this file that creates the layout of the various posts. Index.css contains general styling such as background color and font-style. The last file is used to import images that are set to <IMG> elements as ids to render.

4.3.4 Application

The *Application* component is the parent of all the other components. Application, Header, Menu, and Content are all components with only one existing instance. See figure 4.3.

```
function Application() {
  window.onbeforeunload = function () {
    window.scrollTo(0, 0); //Scroll to top of screen
  }
  return (
      <div className="App">
        <Header />
        <Menu />
        <Content className="Content" />
      </div>
  );
}
```

Listing 4.3: Definition of the Application function component

4.3.5 Header

The header acts as an introduction. It displays a headline and a background image. An arrow button will scroll the user to the first section of the main content. The background image, title, and subtitle seen in figure 4.15 can be changed in the content folder.

Figure 4.15: Screenshot of the header of the web page.

4.3.6 Menu

Hovering the mouse over the left outer part of the screen will open a side navigation menu. A user can easily navigate to sections of the content that they find the most interesting. The navigation also provides a ”table of contents” for the user (see figure 4.16). Consistent with the western **search pattern** described in chapter 2, the menu is placed in the top left corner. In this way, a user hopefully immediately becomes aware of the presence of a navigation opportunity.

The Menu component imports the a file containing the sections from the content folder. It dynamically renders each section "title" as well as automatic scroll navigation to the corresponding section.

Figure 4.16: Screenshot of the side navigation menu of the web page.

4.3.7 Content and Section

A section is defined as a collection of posts. Therefore, all the sections are stored as a list of lists in the code. Each section, and corresponding posts, are rendered using two map functions. See figure 4.4

With React, a list of JSX elements can be injected into other parts of the JSX. When this is done, all the list elements are rendered sequentially from the same parent.

```
/** Two code snippets from the Content component.
sections :: [[{Post object}]]
*/

//First code snippet
return (
    sections.map((section, index) =>
        <Section>{display_one_section(section, index)}</Section>)
   }
);

//Second code snippet
const display_one_section = (section, i) =>
    <div id={"section_" + i}>{section.map((post, index) =>
        <div className='postholder' id={"post_" + (index+1)}>
            <Post /** set post props.. */ />
        </div>)}
    </div>
```

Listing 4.4: Definition of the Application function component

The logic from the code snippets in figure 4.4 results in the hierarchical "section with posts" structure in the DOM. See figure 4.17

Figure 4.17: The DOM resulting from two map functions applied to both section and post.

4.3.8 Post

Functionality and styling for **six** post types have been developed during this project. They are all rendered from an object using the same structure. Each of the values in this object correspond to a property in the Post component. See listing 4.5. This subsection will demonstrate how each post type works and show screenshots from the website that utilize these post types. The visual arrangement of all the posts are created with a CSS module called Flexbox, a tool that allows for flexible and responsive element layout.

```
/**
 * Create a post of type "Scroll", "Sticky", "ZigZag",
 * "Vertical", "Horizontal", or "Testimony"
 * @param String                Header/title of post
 * @param String                Specified post type
 * @param [String]              Pictures
 * @param x                     Div (e.g. sound)
 * @param [String || JSX]       Written content
 * @returns Object              Post object w/ content and
                                specifications
 */


export const create_post = (header, arrangement, pics, misc,
   content) => {
    return ({
        header: header,
        arrangement: arrangement,
        pics: pics,
        misc: misc,
        content: content
    })
}
```

Listing 4.5: Definition of the function that instantiates a *Post manifest*. Creates an object with content and specifications for any post type.

Scroll Post The *Scroll Post* contains a background image and white text boxes with paragraphs that scroll over this image. This post type has a cinematic aesthetic and could be well-suited as an introductory post. Figure 4.18 shows an example of the post type sampled from the website, whereas figure 4.19 illustrates its structure and logic.

All paragraphs and both images are placed inside a div. The images are made ”sticky”, which means that they follow the screen for the duration of the div. The two images are placed directly on top of each other, but only one is showing at a time. After half of the paragraphs in a post have been scrolled past, the image shifts with a transition of 0.6 seconds, and vice versa. The latter is achieved by implementing the last function component, *Scrollama*. The **animated transitions** as a design strategy is written about in chapter 2 (2.3).

Scrollama[10] is a JS library created for ”scrollytelling” . This project uses an adaptation which was made for React specifically [11]. An IntersectionObserver is used to monitor when specific elements, termed *steps*, cross a defined threshold on the screen. Custom responses can be created by first defining which elements are considered steps, then implementing predefined props named ”onExit” or ”onEnter” as functions. These define what will happen once a step enters or exits a threshold.

The library was implemented for two purposes, both indended to enhance the narrative experience. The first use case is image transition for the post types *Scroll Post*, and *Sticky Image Post*. Once the middle paragraph these post types exits the defined threshold, the images transition. This is done by changing the opacity of one of the images to 1, and the other one to 0. The second use case is to turn the opacity of the written content from low to high once a threshold of three fourths of the screen, horizontally, has been reached. This causes the text meant to be read next to be highlighted.

[10]Scrollama by Russell Goldenberg, under MIT License on GitHub.
[11]Scrollama adapted to React by Jason Kao, under MIT License on GitHub.

Figure 4.18: Example of a post with type **Scroll Post** on the website. Screenshots taken from website. Image number four illustrates a 1.5 second transition between pictures once a threshold is met.

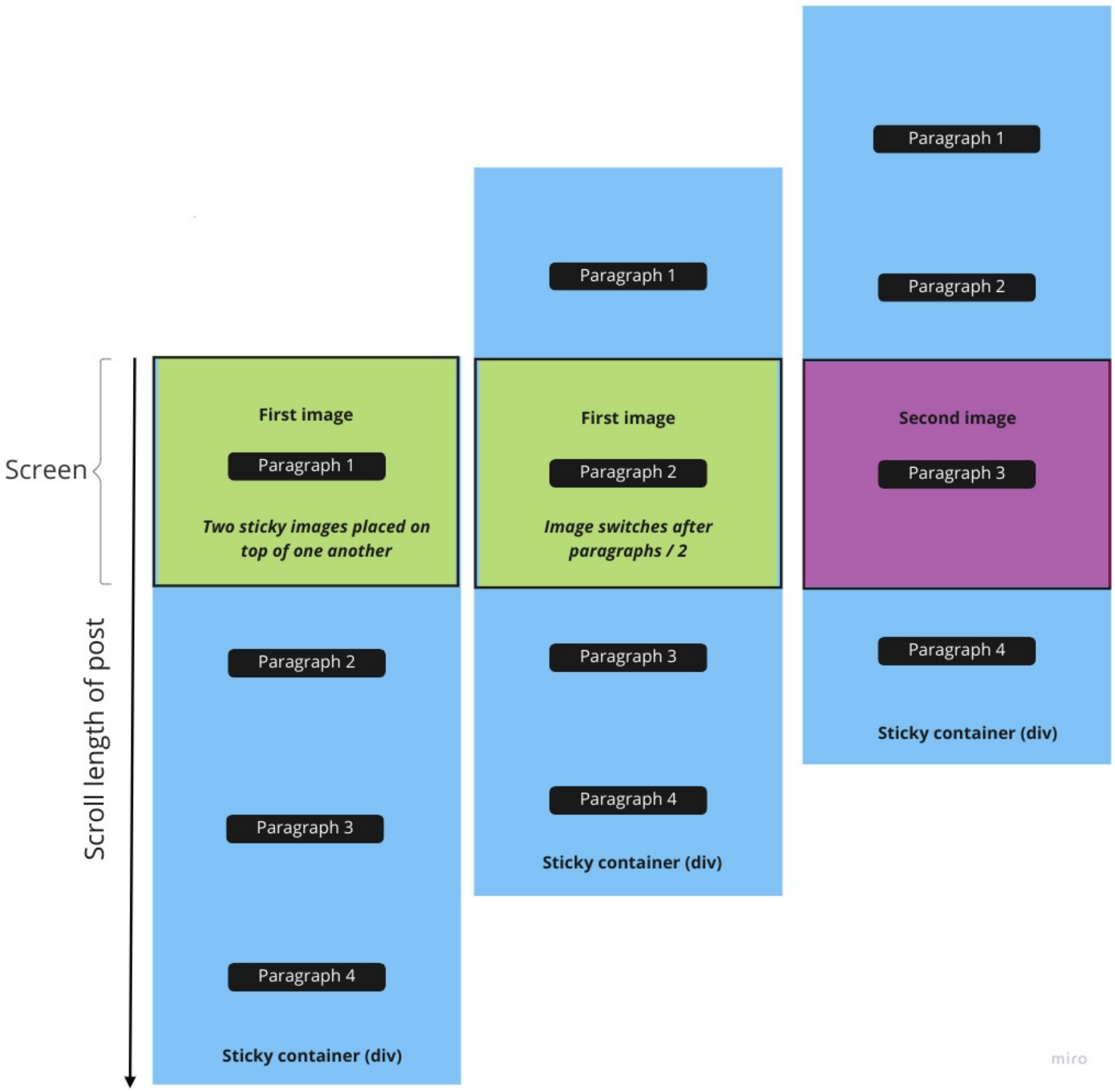


Figure 4.19: Diagram that illustrates how the "Scroll" post works.

Sticky Image Post The *Sticky Image Post* is built with the same functionality as the Scroll Post, but has a different layout with the text to the left, and the image to the right. If a second image is specified, the image changes halfway through reading. See figure 4.20 for a structure diagram.

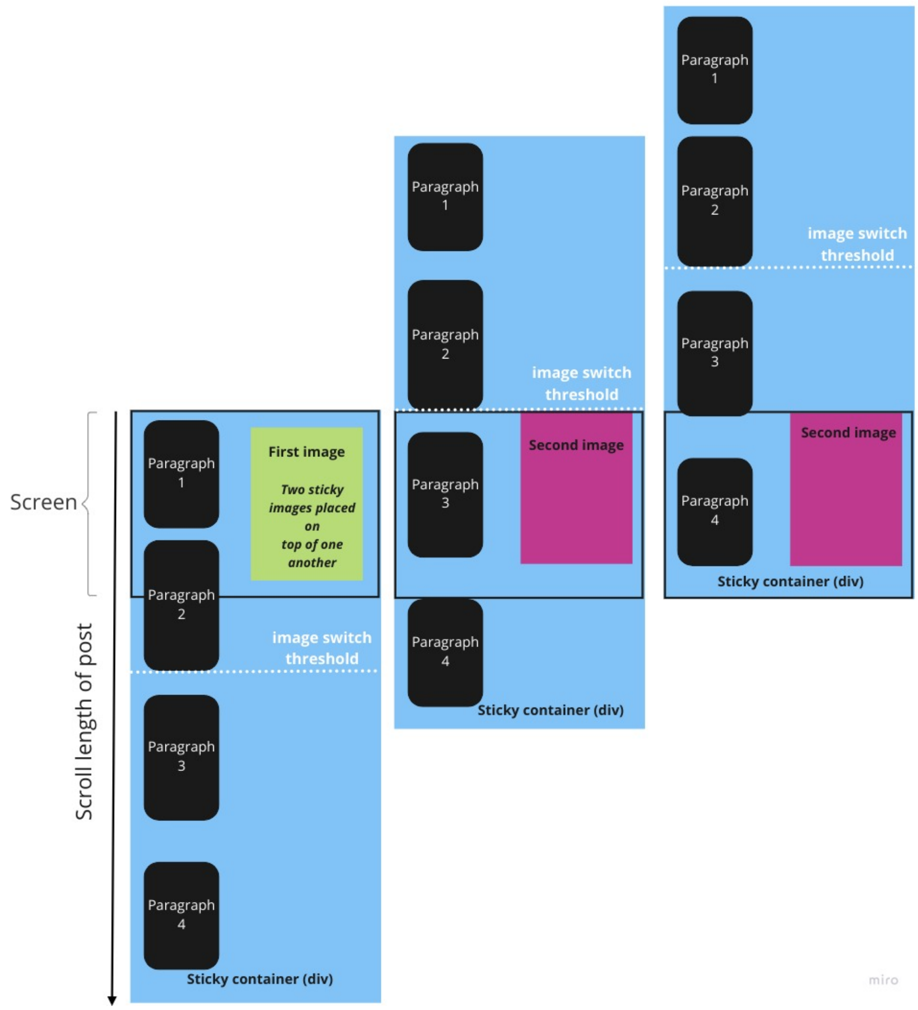


Figure 4.20: Diagram that illustrates how the **Sticky Image Post** works. The first image transitions into the second image once the threshold is passed by the screen, and vice versa.

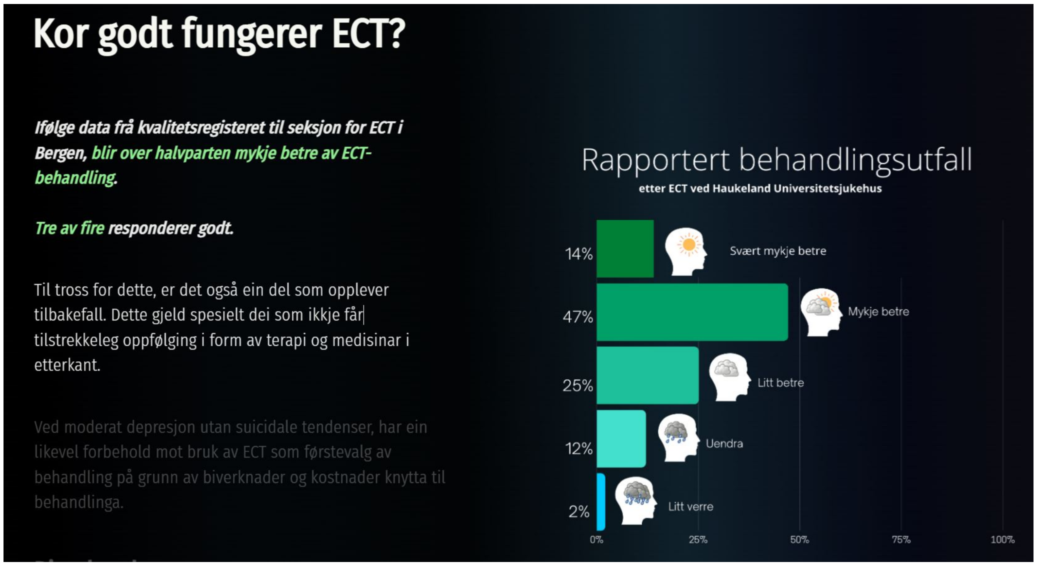


Figure 4.21: Example of the **Sticky Image Post** type before it has transitioned. Paragraphs that have not yet entered the mid section of the screen have been set to have lower opacity.

Figure 4.22: Example of the **Sticky Image Post** type after it has transitioned.

Zig Zag Post The *Zig Zag Post* displays images with corresponding captions in a vertical fish bone pattern. It is focused on the images, and is well-suited if there is a sequential queue of images that tell a story. See figure 4.23.

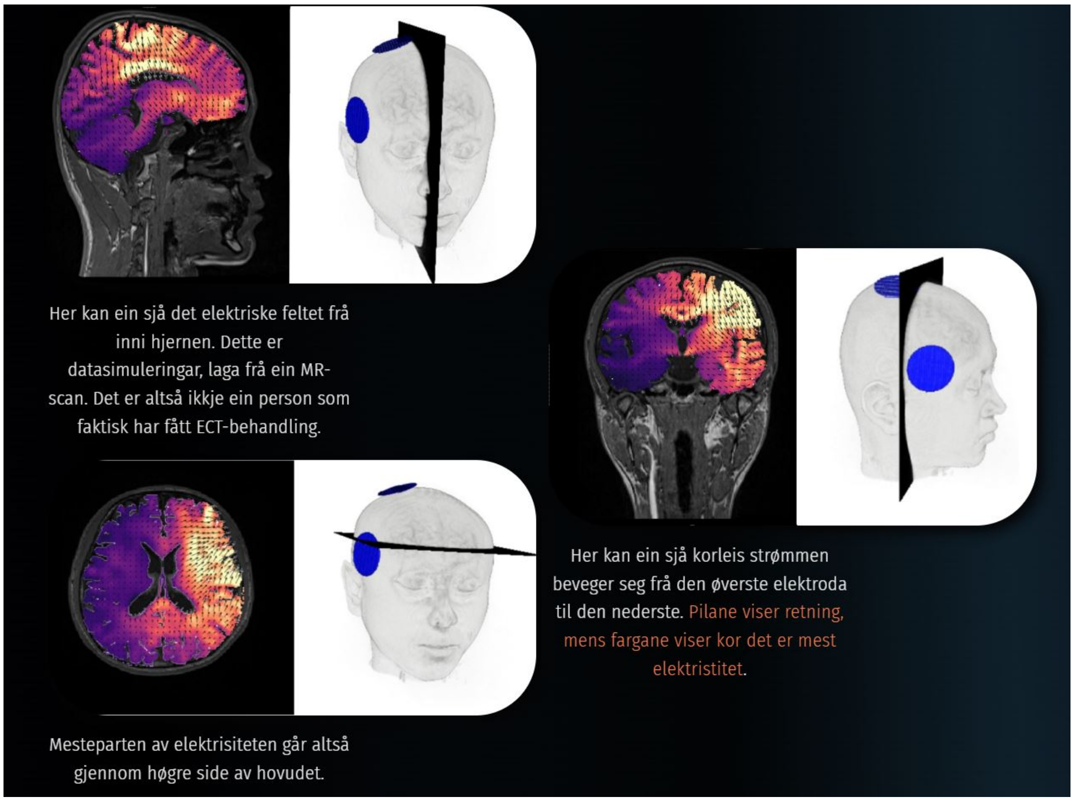


Figure 4.23: Example of the **Zig Zag Post** type.

Vertical Article Post The *Vertical Article Post* displays paragraphs and images vertically. It is similar to that of a digital newspaper or other online article. It is useful for conveying information that has accompanying graphics. See figure 4.24 and 4.25.

Figure 4.24: Example of the **Vertical Article Post** type.

Figure 4.25: Example of the **Vertical Article Post** type.

Horizontal Article Post Images in the *Horizontal Article Post* are horizontally placed next to a paragraph. It is similar to the Vertical Article post, but allows the image to be bound to a specific portion of text. See figure 4.26 and 4.27.

Figure 4.26: Example of the **Horizontal Article Post** type.

Figure 4.27: Example of the **Horizontal Article Post** type. This post was in figure 4.23 rendered as a Zig Zag post. Switching between post types can be easily done by changing the manifest of the post.

Testimony Post Nine pictures are displayed in a three-by-three grid on the *Testimony Post*. A box with a title and an outline is visible on the right side. There is a dynamic text element inside of this box. Each image has an associated text, which is displayed inside the outlined box when a user clicks on one of the photos. On the website, this post type was used to display quotes from real, anonymous ECT patients.

Figure 4.28: Screenshot of the **Testimonies** post type. The images are clickable and will light up on hover. Clicking another image will render a new quote from a real ECT patient.

Here, a design combining principles of **visual salience** and **gestalt principles** are employed. Light-up on cursor hover serves as a **marker of interactivity**. These techniques are described in chapter 2 (2.3).

4.4 Meta of written website content

Alongside the visuals, I developed written content using three different approaches in explaining ECT: Purely informative sections of factual information, chosen testimonies from real patients, along with a fictional patient story that follows the woman "Åse" through treatment. The content of the site (written in Norwegian) can be found in **appedix B**. I also took photographs at the section of ECT at Haukeland University Hospital to use for the website.

A sixty page document of quotes from Norwegian ECT patients was composed to choose representative testimonies. It is not included as an appendix here because of its length. These quotes stem from the national guidelines for ECT[20], a master thesis by Leila Frid named "Patient experiences before, under, and after electroconvulsive therapy" containing phrases from interviews of patients [15], and a qualitative paper on user experiences with ECT [10]. All quotes were gathered and read through, and nine reoccurring comments were chosen for the website's anonymous testimonials. Testimonies that uttered death wishes, suicidal inclinations, and extremely favourable or negative views of ECT, were not included in these nine.

Chapter 5

Evaluation

An assessment of the project is provided in this chapter. It consists of survey feedback on sample visualizations and assessment of the website and its content. Qualitative testing was judged appropriate as this thesis' focuses on subjective experience. The following sections lay out the results from these evaluations.

5.1 Questionnaire

A questionnaire was used to gather input on the medical visualizations, graphs, and illustrations presented in Chapter 4. Responses have been processed to help maintain the anonymity of the participants and increase readability of results. The survey has a total of 19 responses. Several methods were used to find participants: Emails were distributed to MMIV and the ECT user panel at Haukeland. It was published on a small-scale digital medical visualization platform containing students and employees at the University of Bergen. Lastly, some participants were recruited from the author's social network. This resulted in a group of respondents with different backgrounds and relationship with ECT and data visualization.

Open questions, keywords, associations, rankings, and prepared statements with likert scales are combined throughout the survey. A brief written introduction to ECT is given at the beginning, along with questions about preexisting knowledge and occupation. After this, there are assessment of specific visuals as well as some general questions that are pertinent to the research topic. I gave brief explanations for each data visualization were given prior to inquiries. These explanations are shown in **appendix A** in cursive writing.

I calculated summary statistics for the questionnaire results in Excel[1], and the graphs were generated from this analysis. The word clouds[2] and graphs are arranged together with Miro[3].

5.1.1 Scoring

Several visualizations were ranked by preference during the questionnaire. To create draw a meaningful conclusion from the gathered data, a score was calculated based on these rankings. For all tasks with three or more options, the votes are weighted in the following manner,

$$n = options, v = votes$$

$$choice_1(v \cdot n), choice_2(v(n-1)), ..., choice_n(v(n-(n-1)))$$

[1]Excel (version 1.0.0.1)
[2] Copyright © Jason Davies (https://www.jasondavies.com/wordcloud/)
[3]https://miro.com/

5.1.2 Participants

All participants gave their consent to partake in the survey prior to evaluation. Respondents' occupation, relevant expertise, and experience with ECT were noted. Ideally, more detailed measurements of health literacy and more specific background factors should have been included, but this was not feasible due to project scope and time constraints. Figure 5.7 gives an overview of these results. Two subjects reported having color vision deficits; one had mild deuteranopia and the other had self-reported trichromacy.

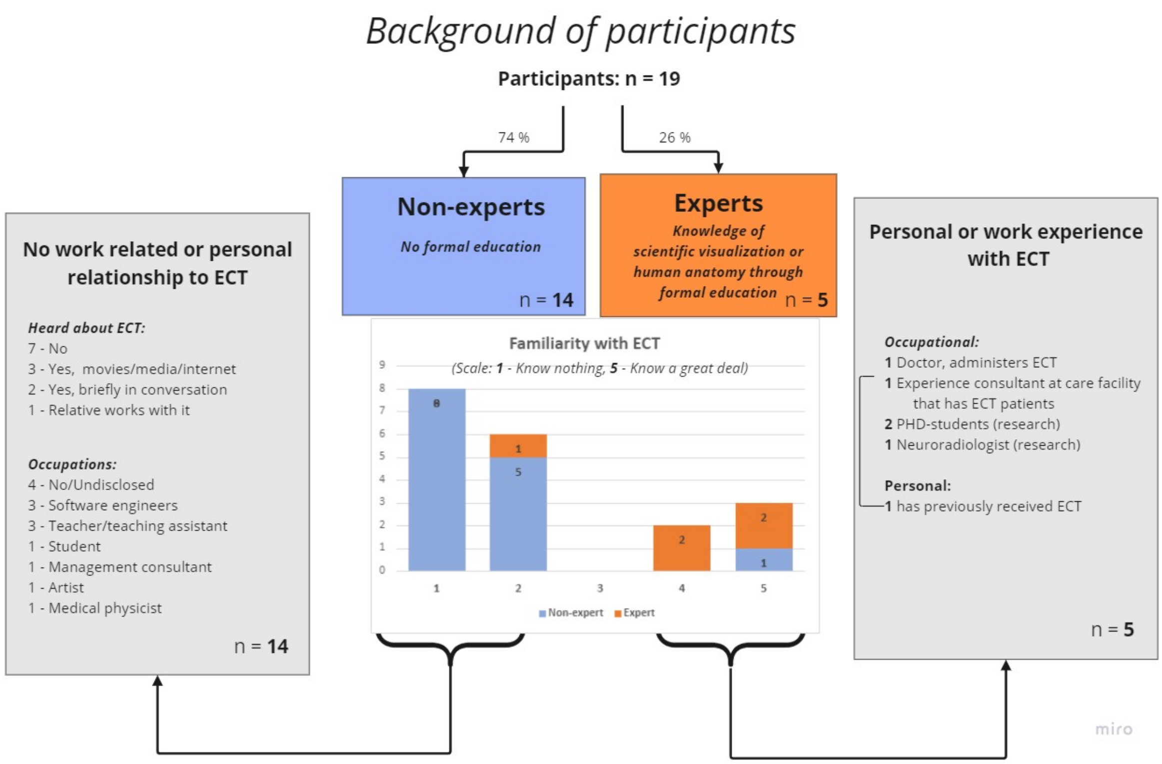


Figure 5.1: Background of participants of questionnaire.

73 percent of the participants were classified as "non-experts", defined here by lack of professional medical education and/or knowledge of scientific medical

visualization. This partitioning is used throughout the rest of the evaluation of results. However, insight in these topics likely varies within these groups; factors that should account for the eligibility of one's expertise are not included here. For instance, the two software developers are more likely to have prior experience with scientific visualizations. The participant who works in a care facility disclosed having both professional and personal experience with ECT, but no formal schooling. The dichotomous division of *expert* and *non-expert* may therefore not be as unequivocal as implied by the categorization.

5.2 Evaluation results

The following subsections present visualized and processed data from the questionnaire. These are all linked to the preferences, comments and associations of the visualizations presented in chapter 4.

5.2.1 Feedback: Displaying medical data to non-experts

The majority of non-expert participants were positive to being shown medical images; out of fourteen non-experts, eleven participants stated that they thought it was helpful to see medical images. This was gathered after having evaluated the medical images and animations presented below, and can be seen in figure 5.2. Two said that they did not know how to interpret them, and one participant said that it was a little overwhelming.

The non-expert participants were then prompted on whether they would like to see *their personal data* displayed in the given scenario that they were to undergo treatment, and were given five options. Three participants answered that they would ”very much like to see their data”. Six responded that it would be ”nice, but not necessary”. One responded that a ”random MRI-scan would be sufficient”, and one answered that they were ”indifferent”. Two respondents said that they would not like to see their data, and a last participant would find it "disturbing".

The participant with personal experience with ECT commented that the shown visualizations were *"Good information. Realistic, engaging"*. Another said *"I think overall they helped me visualize ECT better than having it only explained to me."* Participants were also asked about what associations the images gave them. The answers ranged from media to other forms of data visualizations: *"Perhaps some associations to TV-shows about medicine and hospitals."*, *"Some science fiction films maybe"*, *"Some of them remind me of heat or elevation maps. The plane views reminded me of engineering sheets."*, and *"Some reminded me of maps depicting metrics for a country, ie population density, elevation, rainfall.."*.

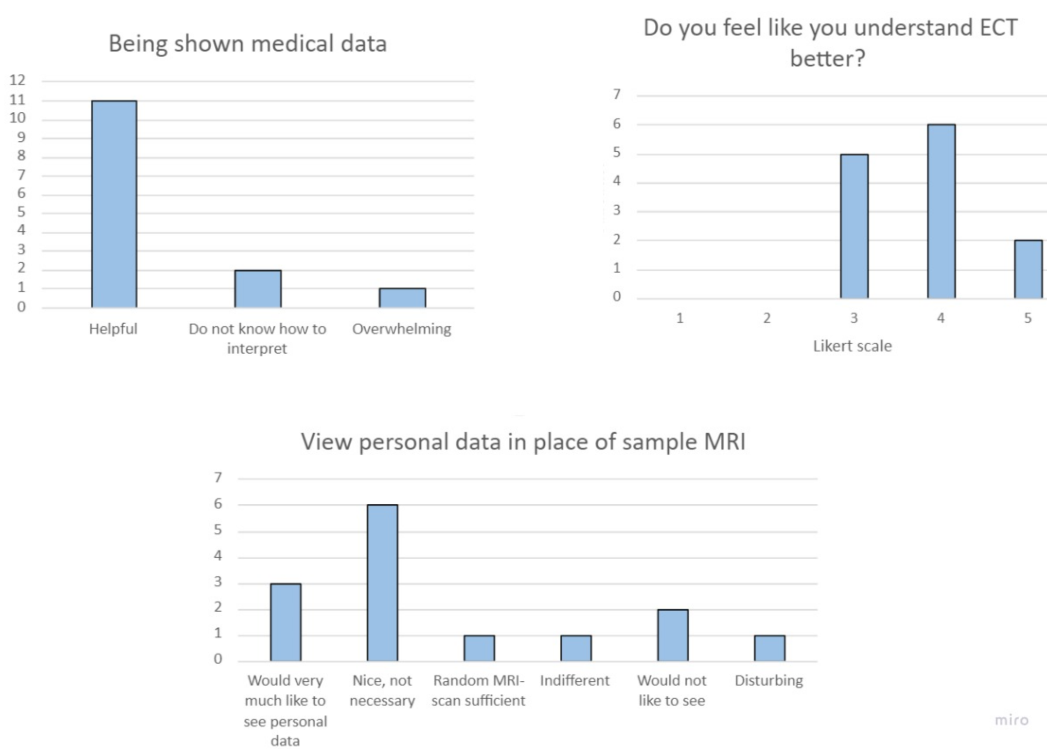


Figure 5.2: Non-expert feedback in being shown medical data.

Although feedback was generally positive, many participants pointed out that it was difficult to understand the information presented to them. Several participants said that it would be nice to have these as visual assets in when receiving an explanation for the procedure, but that it was hard to gain real insight from the visualizations alone: *"I do not understand that much of the illustrations alone, but it is a good tool to use when explaining things"*. One participant commented *"The images are informing and I do believe I can understand a small percentile of them. I do also believe that without the context written to me in this questionnaire, I would be clueless"*. A few questioned the utility value of the visualizations given, *"Helps to image the location of the process but doesn't help explain what its really doing"*, and *"Informative in the sense that I can see the effects of what happens, I cannot explain what that information is useful for however"*. Non-expert participants were asked rate the statement **"Do you feel like you understand the technical aspect of ECT better now than you did before you saw these images? Let 3 be neutral."** on a scale from 1-5. On average, participants rated this a **3.85**. They were also asked **"How much explanation is necessary for the images to be of value? Let 3 be the level of worded explanation provided here (i.e. a small paragraph)"**. The result here was **3.5**.

An interesting divergence between an expert and several non-expert statements was whether they **anticipated the images to have an axiety-inducing or calming effect** on a general audience. One of professionals responded that they believed such photographs would increase a patient's anxiety, *"I think the illustrations will add anxiety to the patient/family. Electric current is considered a hazard, and these illustrations add more anxiety. On the other side, when presented along with other info, could describe better the procedure"*. On the other hand, three non-experts wrote: *"I do believe that people in the situation that is described would try to make sense of what is going on, even though they don't have the necessary knowledge to fully understand the procedure. It would "perhaps" give them a sense of understanding and could help them calm down."*, *"It's reassuring to have some understanding. Or just know that it is possible to be able to see what happens"*, and *"Helping with contextualizing and explaining the procedure someone undergoes allows one to empathize and understand better what they are going through"*.

5.2.2 Color maps: Preferences, comments and associations

Participants were asked to describe, comment on, and rate the various color maps presented in chapter 4 (4.1.3). See table 5.1 below, and figure 5.3. Keywords with associations were collected and presented as word clouds for each scheme.

Table 5.1: Color map preferences.

Calculated preferences for color maps		
	Non-expert	**Expert**
1.	Viridis (score: 46)	Viridis (score: 19)
2.	Jet (score: 45)	Jet/Magma (score: 11)
3.	Magma (score: 30)	Pink (score: 9)
4.	Pink (score: 21)	

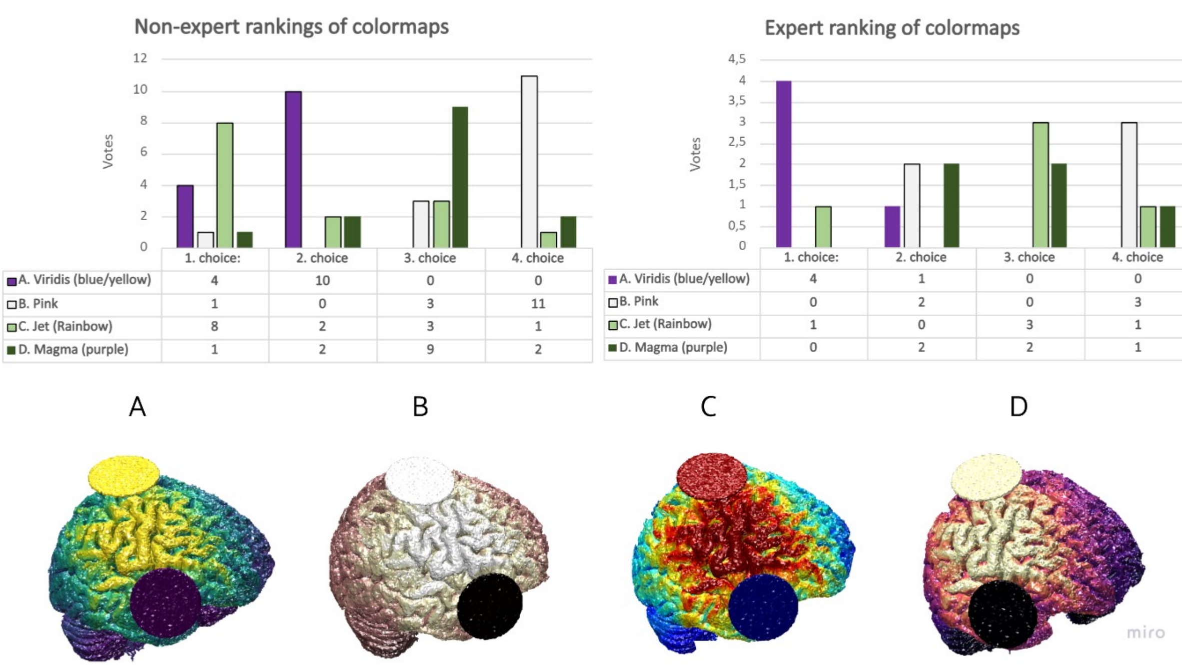


Figure 5.3: Colormap rankings

5.2.2.1 Jet

Both non-experts and experts held differing opinions on the Jet color map. See the keywords mentioned in figure 5.4.

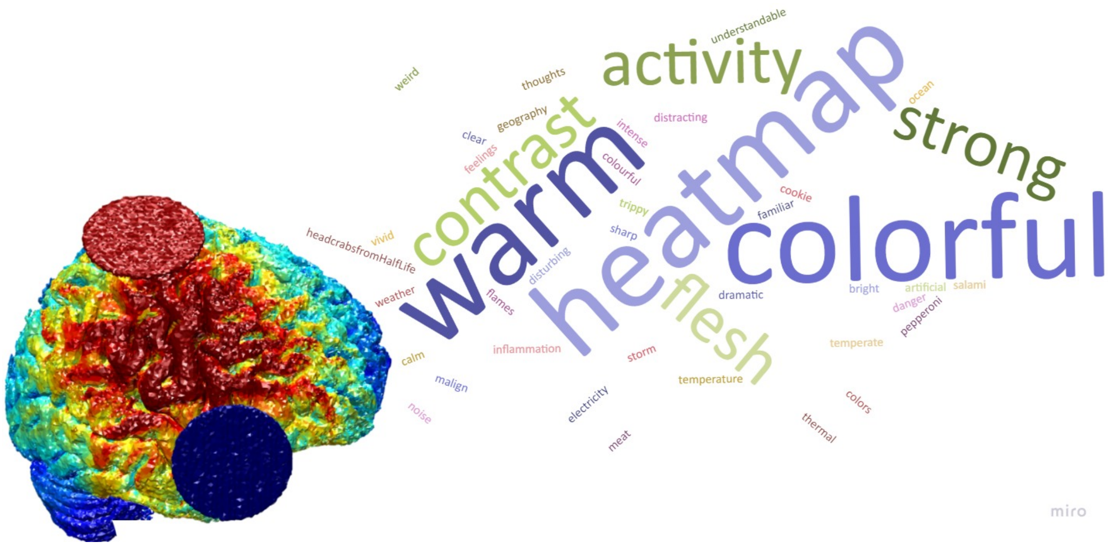


Figure 5.4: Word cloud with results from keyword description of the electric field simulation with color map *Jet*.

Non-experts most commonly selected the Jet color map as their first choice option, although Viridis outperformed it in terms of overall higher rating. Non-experts commented statements like *"not a good gradient"*, *"I wish the fields were different colors"*, *"a little intense, but fine."*, *"it's good and shows changes well"*, and *"it's a good illustration"*. Three non-experts pointed out that the color scheme was **familiar** to them: *"It feels like I've seen this image before. It resembles images you would see on TV-shows"*, *"Colors match with other illustrations showing spread of heat/radiation/etc"*, and *"Easy to understand, most people are familiar with maps of countries depicting elevation, population density (etc.), where red depicts a high value, and blue a low one"*. One participant exhibited a **disconnect from the stated intent** of the visualization. They described the colors as feelings, remarking that *"many thoughts/feelings are flowing through the brain. Or that red illustrates strong feelings that go towards less yellow and most red."*

A non-expert participant showed insight into **color map theory**, reflecting on lack of perceptual ordering, *"It's easy to distinguish between sections, but the colors feel too much and are a bit distracting. The colors feel like sections and not a scale"*.

Experts were scattered in their opinions: *"Dramatic colors indicating serious malignity", "Provides the most detail, pretty", "Gives a good indication that it is an electric field", and "looks dramatic".* An expert working with visualizations pointed out that *"the color scheme does not work for everyone"*.

In summary, many of the descriptive negative comments mainly revolved around the map being **too intense or dramatic**, whereas the positive noted that the colors were **easy to distinguish**.

5.2.2.2 Viridis

Diverse reviews were given to the Viridis color scheme. Keywords are displayed in figure 5.5. All the experts were generally very positive: *"a good color scheme that is uniform and pretty looking", "works nicely when you think of electricity as a lightning strike", "looks kinder (compared to jet)", "clearly indicates the location of the field, without adding feelings to the colors"*, and *"Looks good, but appears to me like some important detail on the field strength is lost".* Positive remarks from non-experts were slightly more toned down: *"great contrast, makes the image quite clear.", "it shows highlighted areas clearly", and "better than the last (jet)".*

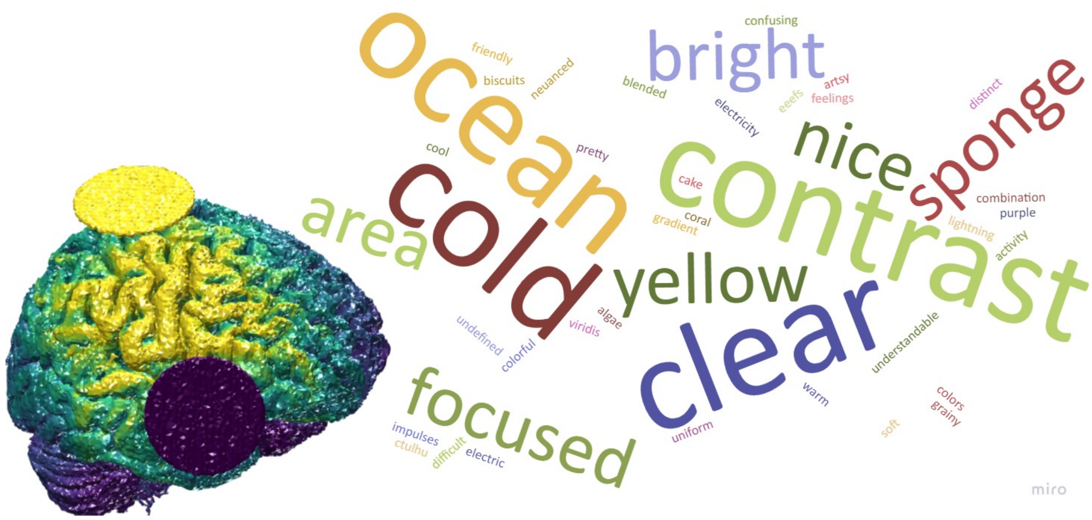


Figure 5.5: Word cloud with results from keyword description of the electric field simulation with color map *Viridis*.

Other comments were either neutral or negative: *"This feels less intense compared to the first one, but the yellow part draws much more noticeable then the rest of the colors."*, and *"colder colors that kind of do not fit the brain".* Two participants noted that the color scheme seemed unfamiliar. One of them noted that, *"its the same as for the red-blue one, but slightly less conventional color scheme"*. As seen, a notice of **regard for color vision deficiency** was observed by this participant. In summary, the **colors were better liked** than the jet color scheme, but some felt that **areas were slightly harder to discern**.

5.2.2.3 Pink

The *Pink* color map was consistently the most disliked color map of the four. Out of the 19 responses, only one was partially positive, *"Easy to read, but even less conventional color scheme"*. See figure 5.6

Negatively associated words such as dull, boring, and creepy were frequently mentioned. In the commentary, several participants indicated that they did not like the the level of realism this color map added. Three participants in the non-expert category stated *"The pink color reminds me of the color of the brain. The yellow looks like something is rotting and losing its color. The gradient resembles the way something naturally would've lost its color. Looks worn."*, and *"Feels like something you would see in a museum"*. Another person said: *"Pretty colors are welcome. And I feel that if the brain looks too realistic (pink colors, shadows etc.) it becomes creepy*. Two participants noted that it looked metallic. Difficulty in reading data were uttered by both by experts and non-experts: *"Don't see any info on the electric field"*, *"bit difficult to identify borders"*, and *"white field is somewhat hidden"*. One participant noted the lack of **visual salience**, *"does not pull focus to highlighted area"*, and another the lack of association to what was actually being visualized *"has no electricity-related association"*.

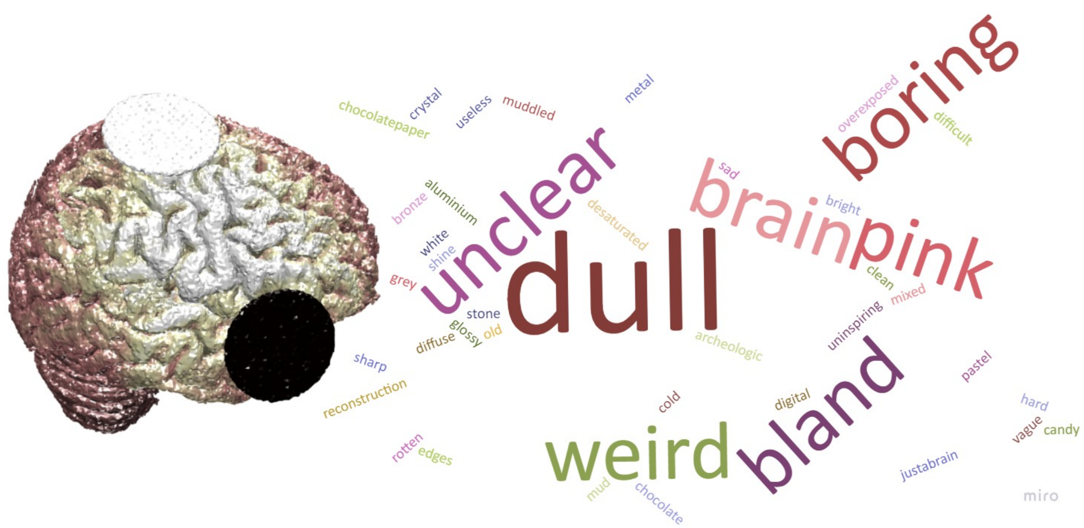


Figure 5.6: Word cloud with results from keyword description of the the electric field simulation with color map *Pink*.

5.2.3 Magma

Magma was rated third out of the four color schemes. There were several comments about the aesthetics of the color map, such as *"A little too aesthetically pleasing"*, *"too strong and wrong colors"*, *"It gives a good visual, but maybe a bit too intense purple"*, and *"I feel the purple and the bright yellow-ish colors are very easy to distinguish between. And I like purple"*. Negative comments were centered around contrast and how it was **difficult to differentiate areas** with similar activation: *"The brightest is very bright, but everything else is quite dark"*, *"OK, but the deep purple is a little hard to differentiate"*, and *"hard to identify borders in the purple area"*.

Four of the nineteen respondents pointed out that color scheme was **opposite of what one might expect**: *"Feels a bit backwards"*, *"Unnatural with the highest color (warmth) where there is no stimulation"*, and *"Appears wrong as non stimulated areas are coloured. Helpful for such illustrations"*.

Figure 5.7: Word cloud with results from keyword description of the the electric field simulation with color map *Magma*.

5.2.4 Abstraction levels

Both non-expert and expert participants had a clear preference for the most detailed image. *"More detail"*, and *"more information"* was listed several times as the reason for choosing this as the first choice. The context of the electrodes to the brain was also listed as a reason. The image with a medium abstraction level was consistently disliked:*"I felt like it had too unclear details. I can barely see the outline of the brain. This one was a bit more tiresome to look at since there are details that I can't really make out"*. See figure 5.8.

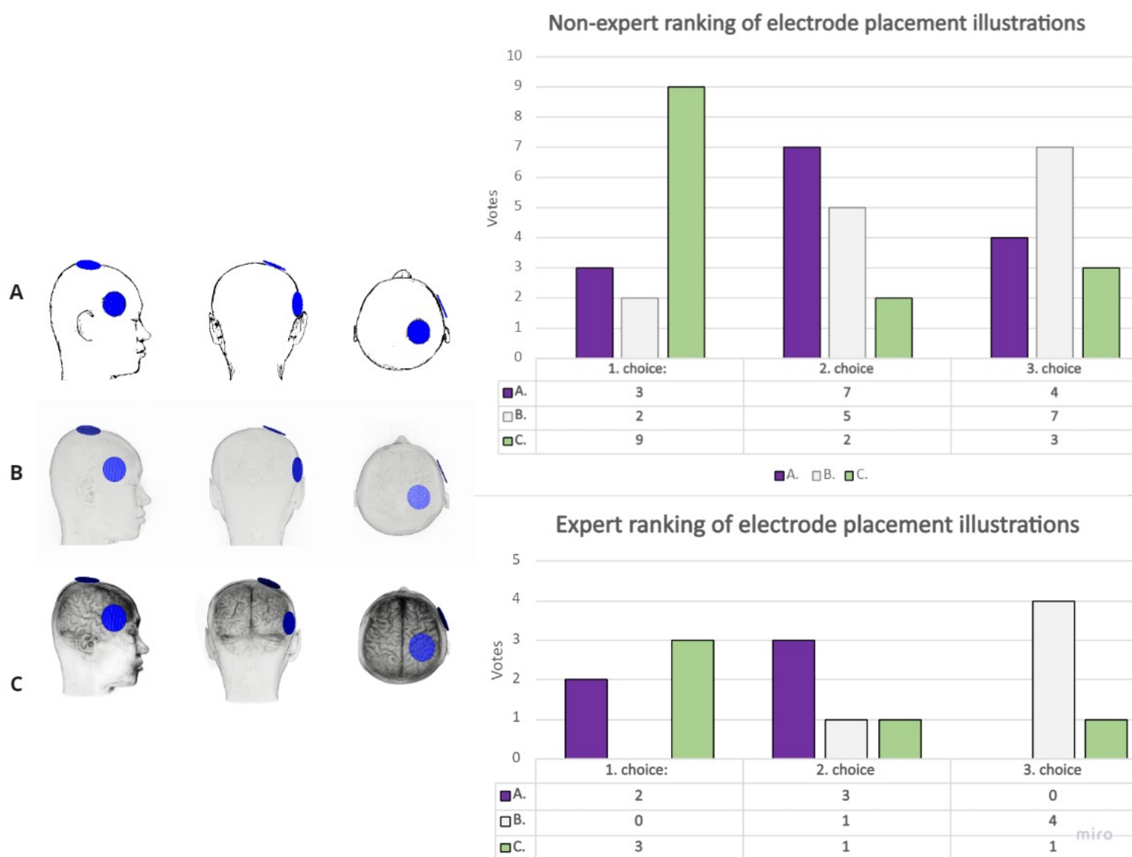


Figure 5.8: Expert and non-expert ranking of electrode illustrations with different abstraction spaces.

5.2.5 Neuroimaging planes

The Axial plane was preferred by both non-experts and experts. There illustrations received mixed feedback, but nearly all participants stated that they understood the contexual images to the right of the MRI. Negative comments were that it was *"difficult to interpret what the different version of slices depict"*, whereas positive ones stated that it *"it does a good job showing where the electric field is strongest"*. One respondent remarked that the eyes visible in one of the MRI-images were *"freaky"*. See figure 5.9 and table 5.2.

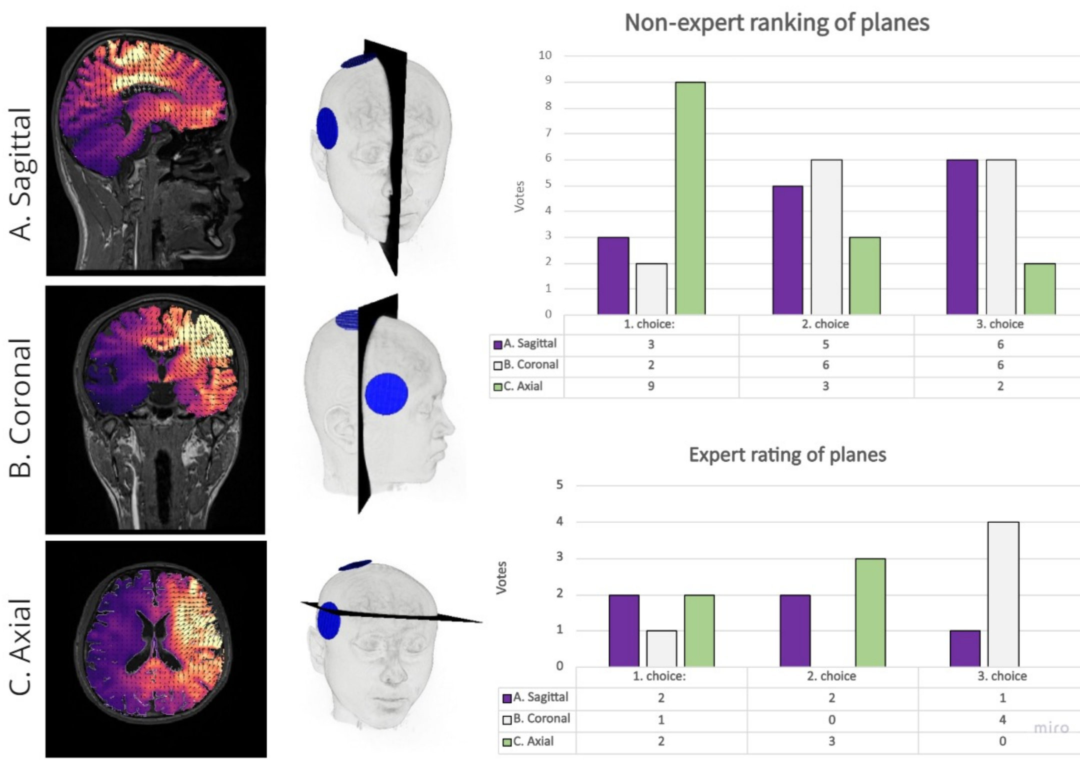


Figure 5.9: Participant ratings in preferred MRI plane showing the electric field in the brain generated from electric stimulation from TES.

Table 5.2: MRI-plane preferences.

Calculated preferences for planes		
	Non-expert	**Expert**
1.	Axial (score: 35)	Axial (score: 12)
2.	Sagittal (score: 24)	Sagittal (score: 11)
3.	Coronal (score: 24)	Coronal (score: 7)

5.2.6 Angles

The preferred angles were similar for both professionals and non-experts. Views that clearly demonstrated brain activity were preferable. A mix of views that provided an adequate overview of the electric field was described as ideal. See figure 5.10.

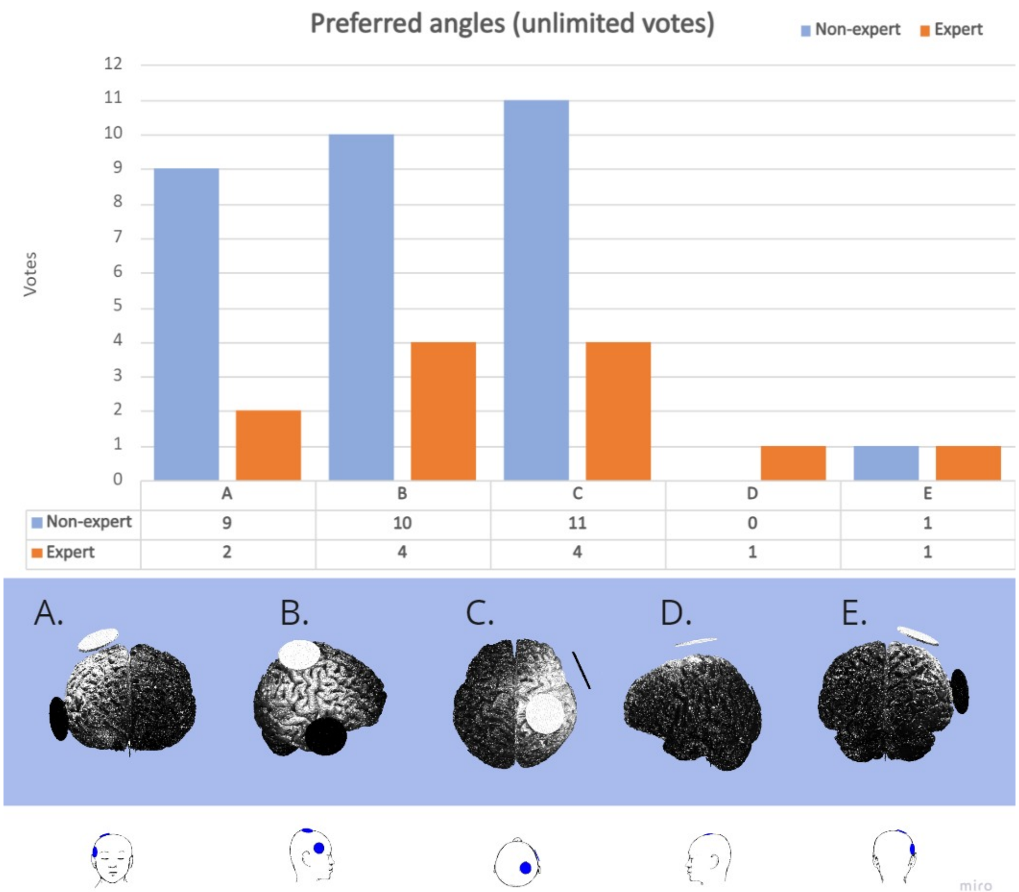


Figure 5.10: Participant votes on different angles displaying the electric field on the cortical surface of the brain generated from TES.

5.2.7 Graphs

Participants were tasked to rank the various graphs by preference. Graph A was most frequently chosen as a first choice for non-experts, whereas graph B was preferred by experts. More than two thirds of non-experts chose C as their least favorite. See figure 5.11[4] and table 5.3.

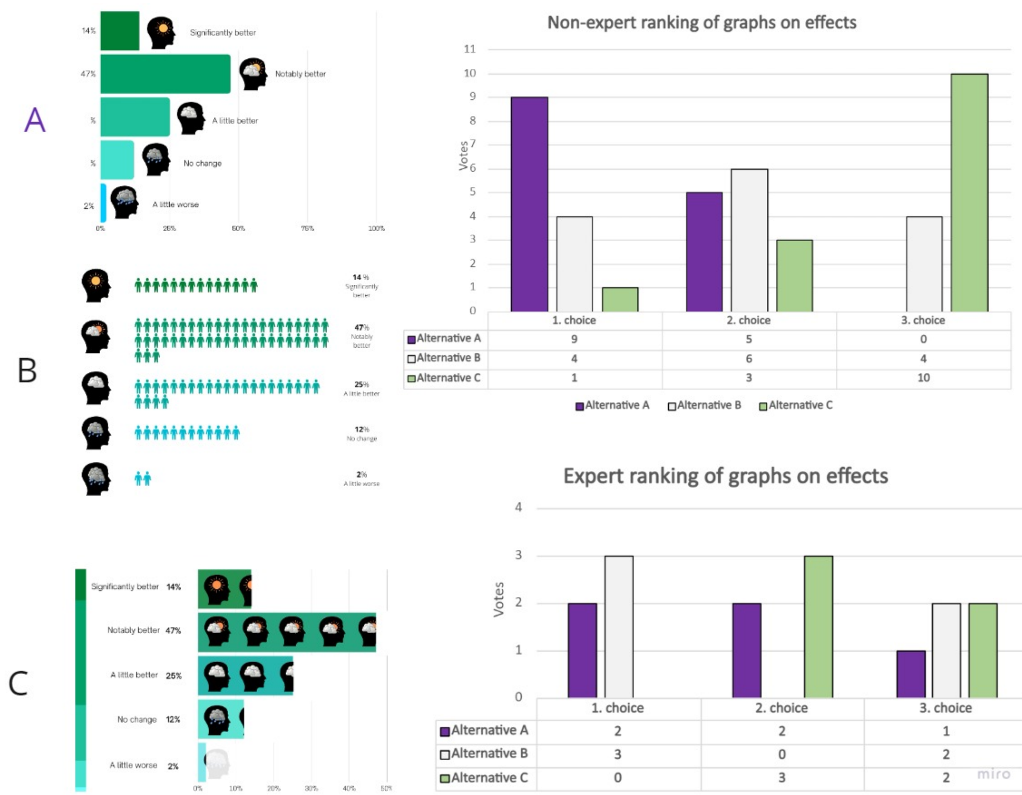


Figure 5.11: Participant ranking of graphs showing statistics on the effects of ECT.

[4]Four of the first entries for non-experts were by accident published with a 1-10 scale rather than a 1-5 scale for graph B and C. This was corrected after these four participants answered. During analysis, these entries were divided by two in order to process the data and calculate a preference score.

Table 5.3: Preferences in graph styles.

Calculated preferences for effect graphs		
	Non-expert	**Expert**
1.	A (score: 37)	B (score: 11)
2.	B (score: 28)	C (score: 8)
3.	C (score: 19)	A (score: 7)

Graph B in figure 5.12 was a clear favorite amongst both experts and non-experts. A suggestion from the participants was to have the same amount of people for each symptom for easier comparison.

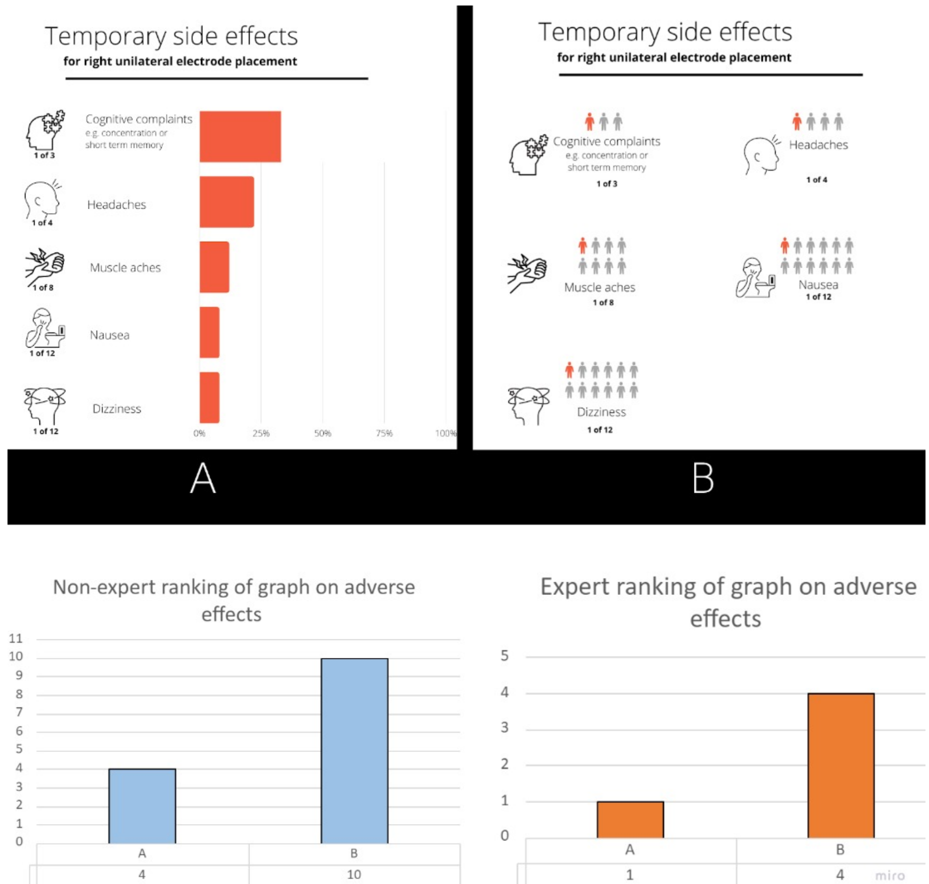


Figure 5.12: Participant ranking of graphs showing statistics on the temporary adverse effects of ECT.

Participants were asked about color- and isotype usage in the graphs. One person noted that: *"The infographic with people feels easier to immediately absorb than the percentages"*. Several people felt that the weather metaphor was too simple to depict severe mental illness: *"Not my favorite, feels kind of simplistically and reductive of the complexities of mental states"*.. An expert agreed and came with two objections. They wrote that *"A severely depressed patient seldom describes their condition with rainy weather, but far worse things such as darkness, paralysis, and more drastic adjectives. This is not picked up by the weather analogy"*. They also commented the lack of gradation in symptoms in the isotype showing a nausea (a person about to vomit) for adverse effects. Having only a few colors that were semantically consistent with their intended message were well received by nearly all participants.

5.2.8 Illustrations

All except two non-experts said that they found it both interesting and relevant to see ECT-machine measurements. The remaining two were either neutral or found it "interesting, but not relevant". Almost everyone stated that they preferred having *both* a text label and a small illustration for the ECT-machine recordings. The calendar illustration was interpreted very literally by most of the respondents, consistent with the findings in literature reviewed in chapter 2. The visualization was intended to be general, indicating that treatment happens three days a week (Mondays, Wednesdays and Fridays). Instead, it was often interpreted as a specific treatment plan that went over three weeks.

5.2.9 Animation versus still images

Participants were asked to choose between still images or animations on the three different kinds of medical visualizations. In the visualizations on electrode placement and three dimensional view of the brain, there were no **clear preference in choosing between animation compared to still images**. Based on commentary individual preference, the purpose of the visual and context seemed to influence this choice. The only exception were for neuroimages, where most participants were inclined to choose a static image over animation. For this particular comparison, the image with an MRI showing the electric field was preferred to an animation fading the layer displaying the electric field in and out. Proponents of animations liked the spatial feel an animation offered: *"The animations of the head and brain seems to give a good understanding of the location of the pads, and does so in a rewarding and quick way. The animated*

MRI didn't give me any insight into what is happening". Some participants proposed that a good solution were if they were able to control the movement of visualization themselves. Proponents of static images stated that it was easier to study things that are not moving, that it was more calming, and that the movement was distracting. It was stated that animation should be used purposefully, and only when doing so adds to the value of a visual representation.

5.2.10 Aspects of data visualizations

The subjects were asked to rate the importance of aesthetics, context, clarity on a scale from 1-5. See results in table 5.4.

Table 5.4: Rating of visualization attributes in terms of importance. Scale from 1-5.

Perceived importance of visualization qualities		
	Non-expert	**Expert**
Aesthetics	3.7	4.2
Clarity	4.8	5
Context	4.5	4.2

5.3 Website assessment

The questionnaire has collected feedback on the visual assets of the website. The written content containing factual information and the narrative was read through by various people. Co-supervisor Leif, and one of his research associates, looked through the content and gave feedback. An ECT nurse from the user panel read through the text more thoroughly and gave detailed feedback on routines and agency-specific data (3.3), spelling, and other aspects about the information and story.

The website in its entirety was presented to the user panel for ECT at Haukeland University Hospital. I made concrete revisions based on the feedback received there, which are as follows: Images not relevant to ECT (e.g. images of decorative elements at Haukeland) were removed to avoid confusion. Factual information was moved to the top part of the website to highlight the most crucial aspects of treatment. Originally, the text altered between sections of factual information and sections of Åse's story. Long sentences were shortened, and corrections to language and grammar were made.

Further revisions should be done by medical professionals if the content is to be used at Helse Bergen as a patient resource. Additional programmatic revisions are needed in order to make the site compliant with Web Content Accessibility Guidelines[5] (WCAG) which are required by Norwegian law. These regulations ensure that the web is accessible to everyone despite physical or cognitive disabilities. The current version is only optimized for web clients. Measures should be taken to make it more responsive and better suited for phone and tablet browsers if distributed.

[5]Norwegian Web Content Accessibility Guidelines (WCAG)

Chapter 6

Conclusion

This chapter concludes this thesis. A summary containing key insights discovered during this work is found below, followed by a brief discussion of the completed study as well as potential future avenues of exploration.

6.1 Summary

This project has entailed developing an information source about electroconvulsive therapy in the form of an interactive, scroll-based website. The work I present in this thesis consists of a variety of assets. There are medical imaging-based visualizations, illustrations, graphs and written content about electroconvulsive therapy. These are put in context and presented with different narrative styles on the website. Provided in this thesis is documentation for the online solution's source code by outlining its components and architectural design, which supports six configurable post types. Additionally, there are two documents that are written for this purpose. One that has short explanations for the visualizations concepts here (appendix A), and one with the contents of the website (appendix B). The latter consists of facts about electroconvulsive therapy, nine testimonies from real patients, and a story about a fictive patient.

Key insights from the qualitative evaluation of these results are as follows:

- The majority of non-expert participants who partook in the evaluation found it valuable to be shown medical imaging-based visualizations. Many participants found it difficult to fully comprehend the assets, but nonetheless found them helpful to view.
- Weather as a metaphor for mental state was generally well understood, but were by some found distasteful and reductive as a representation of severe depression.
- Small illustrations were effective assets in visualizations and helped the reader quickly orient in the visualization. However, these were by some also deemed too reductive and inept at conveying the gradation of patient symptoms.
- Minimal, and semantically consistent, color usage was effective in communicating data in the graphs created here.
- In general, participants preferred color maps that were vibrant and had distinct regions; Jet and Viridis were favorites for these reasons. Magma was considered challenging to read with too bright and too dark regions. Almost all participants disliked pink because it was too realistic-looking, dull, and colorless.
- The axial plane of an MRI was preferred by both experts and non-experts.
- Clarity was rated the most important quality in visualizations in general by both experts and non-experts.

6.2 Discussion

A limitation to the qualitative evaluation in this thesis is that health literacy (and other aspects that might obstruct understanding) are not measured. The participants in the questionnaire stem from a relatively homogeneous group, and many participants have higher education. This means that the group of low literacy individuals whose interpretation are particularly interesting to the evaluation are likely not represented at all. Additionally, evaluation linked to understanding only measures perceived understanding, not actual comprehension of the material.

Various color maps were chosen to visualize transcranial electric stimulation. It may be argued that when showing medical data to non-experts, precise data representation is less crucial than it is for academics and physicians. However, appropriate regions of interest should be properly accentuated and chosen color maps should respect a wide audience of viewers. Although non-experts may not be able to identify color map shortcomings, an ethical regard for their informed consent should be to represent data as truthfully as possible.

This highlights another point. It is reasonable to assume that medical data presented to patients (and which decisions then are based upon), have a real a impact on peoples' lives and health. Creators of medical narrative visualizations in particular hold the moral obligation to portray data as truthfully as possible. Narrative scientific depiction of data, especially in health contexts, cannot take the same liberties of exaggerating information as other media content producers. Given the premise, a mantra *should* therefore be to inform, rather than to convince.

Building narratives that are representative for underlying data can be challenging. The act of *"storytelling"* appears to be frowned upon in certain scientific environments, and criticized when used to portray scientific information. Anecdotal evidence often lacks nuance, and can skew data by highlighting irrelevant information or front data that is in misleading or even in direct opposition to empirical knowledge. News articles can front sensational breakthroughs that are captivating and easy to remember, and fact may be hard to distinguish from fiction. Arguably, a lack of credibility and dissatisfaction in part stems of frequent misuse in commercial contexts. However, by making health information more approachable, narrative medical visualization may have a special chance to engage and educate individuals in their own health. Whether health data presented as a stories *are perceived as credible* by viewers could be an exciting subject for future exploration in this domain.

6.3 Conclusion

This thesis work has included producing visualizations explaining electroconvulsive therapy, and developing a website that place this material in an explanatory, narrative context.

I gave a presentation of this thesis work at the Global ECT-MRI Research Collaboration [1] (GEMRIC) workshop on the 10th of September 2022. GEMRIC is an international initiative where researchers collaborate to better understand the treatment mechanisms and predictors of clinical response in relation to the brain alterations brought on by ECT. The presentation contained preliminary study results and a video demonstration of the website. International workshop attendees expressed interest in these results, and several voiced a desire to implement a similar information resource in their own departments. The section for ECT at Haukeland University Hospital has voiced an interest to launch this website and make it available for patients, caregivers, and interested members of the general public.

[1] The Global ECT-MRI Research Collaboration workshop, 2022 workshop

List of Acronyms and Abbreviations

2D two-dimensional.

3D three-dimensional.

CSS Cascading Style Sheets.

DOM Domain Object Model.

ECT electroconvulsive therapy.

HTML HyperText Markup Language.

JS JavaScript.

JSX JavaScript XML.

MRI Magnetic resonance imaging.

OOP Object-Oriented Programming.

ROAST Realistic, vOlumetric Approach to Simulate Transcranial electric stimulation.

TES trancranial electric stimulation.

UI user interface.

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Appendix A

Explanations given to participants during survey

Brief explanations for each data visualization were given prior to inquiries. These explanations are shown here in cursive writing.

Explanation of medical images *All of the images you are about to see are computer simulations created from an MRI-scan of a head. The person has not, to our knowledge, ever undergone ECT. In the next sections we will ask some questions about the simulations. There are no right or wrong answers to these questions.*

Explanation of procedure *A short, controlled seizure is brought on by the electricity that is applied to a person's head during ECT. The electricity is administered for up to 8 seconds via electrodes placed on the head, and this triggers a seizure which will last for around 20-60 seconds. The patient is asleep and the procedure is painless. During electric stimulation in ECT the current passes from one electrode to the other electrode.*

Explanation of electrode placement *The most common electrode placement in Norway is called RUL (right unilateral), where two electrodes are placed on the right side of the head. The current is conducted from one electrode to the other. In RUL, the current passes from top right of the head and down to the right temple.*

Explanation of electric field on cortical surface *These images depict the electric field on the surface of the brain (with RUL placement of electrodes). This field decides how strongly an incoming current is pulled or pushed, and in which direction. The bright areas on the brain indicate where the electric field is strong, and will push/pull the incoming current from the top electrode towards the lower electrode.*

Explanation of keyword description *For each image, describe the image with 3 words. It can be associations, feelings, notions or purely descriptive. It can be of neutral, positive or negative connotation. Anything.*

Explanation of MRI planes *When looking at MRI-images there are three points of view, called planes, to differentiate between: Axial, sagittal, and coronal. Simplified, it can be seen as from above the subject, the profile of the subject and from behind the subject.*

Explanation of electric field on MRI images *We are to look at the electrical field from before one more time. This time from inside the brain. With RUL, right unilateral electrode placement, the electrical current is primarily conducted through the right hemisphere of the brain. The size and length of the arrows indicate the electric field strength and in which direction the current will travel. The colors indicate the strength/intensity of the electric field at a certain point.*

Explanation of statistics *ECT is the most acutely effective treatment for severe depression. Many feel better within two weeks after the treatment has started. However, ECT is linked to some side effects. Here are some statistics linked to ECT.*

Explanation of ECT-machine print out *This is the start of the seizure. The top two measure electric activity in the brain. An electrode attached to the arm of the patient measures muscle activity. The bottom line shows the hearts electric activity. The timer at the bottom shows the duration of the seizure (in seconds). The seizure lasted for 38 seconds.*

Explanation of treatment course *A treatment usually consist of 6-15 sessions of ECT. At the section for ECT at Haukeland, three treatments are given each week until the patient is done* (*mon-wed-fri*)*. Treatment parameters can be adjusted under the course of the treatment if the patient experiences discomfort or adverse effects.*

Appendix B

Written content of website

The content below was written by the author of this thesis for the purpose of this project. It was authored to place the data visualizations in an explanatory, informative and engaging context. It contains sections of factual information about electroconvulsive therapy, testimonies from real patients, and the story of a fictional patient. Some of the context of the content is lost as it is originally displayed on the website along with narrative elements such as images and other scroll- or click-triggered effects.

B.1 Content

ECT-behandling - Kva er det, og kven kan få det?

Hils på Åse. Åse er 39 år, og er bosatt i utkanten av Bergen. Der bur ho med ektemannen og sine to døtre. Før ho fekk born, pleide ho og kjærasten å gå mykje i fjellet. Slik ho føler seg no, kjenner ho ikkje lenger glede ved å vere ute i naturen. Ho har slost lenge mot depresjonen sin. Den har vore meir eller mindre periodisk sidan starten av 20-åra. Terapi har fungert dårlig eller ikkje i det heile tatt. Samme med medisinar. Åse er ikkje *ein ekte person. Historien hennar er oppdikta for å fortelle korleis ECT i praksis kan sjå ut. Vi følger Åse vidare om litt. Først skal vi fortelle litt om ECT.*

Elektrokonvulsiv terapi

ECT står for elektrokonvulsiv terapi. Behandlinga innebærer at ei kontrollert mengde strøm sendast gjennom hjernen via to elektrodar. Dette utløyser med vilje eit kort krampeanfall. Pasienten er i narkose.

Behandlinga fremstillast ofte svært dramatisk i film, tv-seriar og anna underhaldning. I realiteten er det ei behandling som går rolig for seg. Behandlinga er trygg og skånsam, og kan vere livreddande.

Kva er målet med behandling

Målet med behandlinga er å redusere depressive symptomer. Den som er deprimert har det tungt og slit med å takle kvardagen. Ein håper på å få pasienten ut av vonde tankemønstre slik at dei kan gjenvinne dagleg funksjon og handtere vonde kjensler betre.

Kven kan få ECT?

Det finst ulike indikasjonar for bruk av ECT. I Noreg blir det oftast brukt i behandling av moderat til svært alvorleg depresjon, ved alvorleg fødselsdepresjon, og ved nokre former for mani hos personer med bipolar lidelse.

Ein kan ofte kan merke betring raskt etter behandlingsstart, noko som elles kan ta lang tid med medisinar og terapi. Dette gjer at ECT er eit egna alternativ for personer som står i fare for å ta sitt eige liv eller slit med alvorleg spisevegring.

ECT er særleg egna for personer med behandlingsresistent depresjon. Dette vil seie at samtaleterapi og medisinar ikkje har hatt effekt.

Korleis foregår behandlinga?

ECT innebærer at ein tilfører ei kontrollert dose strøm til hjernen til ein pasient gjennom to elektrodar som holdast mot hovudet. Strømmen førast frå den eine elektroden til den andre. Behandlinga blir gitt under narkose og er smertefri. Strømmen, som gis i opp til 8 sekunder, utløser så eit kortvarig krampeanfall som varer frå ca. 20-60 sekund. Dette kan likne litt på eit epileptisk anfall.

Muskelavslappande medisiner blir gitt under narkosen for å forhindre muskelkramper som gjer at pasienten kan skade seg. Denne blir gitt gjennom ei venekanyle, altså eit lite plastrøyr i armen. Underveis passar eit team med legar og sjukepleiarar på hjerterytma og pusten til pasienten. Den elektriske aktiviteten i hjernen blir også målt.

Den vanlegaste elektrodeplasseringa som brukast i Norge kallast RUL (right unilateral). Her er to elektrodar plassert på høgre side av hovudet. Strømmen ledast frå den øverste elektroda til den nederste som er plassert på tinningen. Ein kan bruke bilateral elektrodeplassering. Denne benyttast når RUL av ulike årsaker ikkje kan tas i bruk.

Eit behandlingsløp består vanlegvis av 6-15 enkeltbehandlinger. Det blir gitt 2 til 3 behandlinger i uka frem til ein er ferdig, og ein kan jusetere på parametere ved behandlinga underveis dersom ein opplever ubehag eller biverknader.

Informert samtykke

ECT er ein frivillig behandling, og eit skriftlig samtykke skal alltid vere på plass før ein igongsetter behandling. Pasienten skal vere grundig informert om kva behandlinga innebærer. Unntaksvis kan ein gje ECT uten samtykke, på det ein kaller nødrett. Ved nødrett er det fare for livet til pasienten, og ein gir ECT som livreddande behandling. Når faren for livet til pasienten er over, må pasienten samtykke til vidare behandling med ECT.

Verknad og biverknader

Effekt: Kor godt fungerer ECT?

Ifølge data frå kvalitetsregisteret til seksjon for ECT i Bergen, blir over halvparten mykje betre av ECT-behandling. Tre av fire responderer godt. Til tross for dette, er det også ein del som opplever tilbakefall. Dette gjeld spesielt dei som ikkje får tilstrekkeleg oppfølging i form av terapi og medisinar i etterkant.

Ved moderat depresjon utan suicidale tendenser, har ein likevel forbehold mot bruk av ECT som førstevalg av behandling på grunn av biverknader og kostnader knytta til behandlinga.

Biverknader

Ein kan oppleve forbigåande biverknader under behandling og i kort tid etterpå. Desse kan inkludere symptomer som hodepine, kvalme, trøtthet, muskelsmerter, svimmelhet og vanskar med å huske ting som har skjedd rundt tida ein mottar behandling. For eksempel kva ein åt til middag dagen før eller at ein hadde besøk av eit familiemedlem. Ein kan også slite litt med konsentrasjonen og føle seg litt ør. Fleire opplever at desse symptomene blir betre underveis i behandlingsløpet.

Sengeposten og seksjon for ECT følger med på kva bivirkninger den enkelte får underveis, og vil justere behandlinga fortløpende dersom det er behov for det grunna bivirkninger. Til dømes vil pasienten få kvalmestillande i forkant av narkosen dersom dei opplever kvalme ved behandlinga. Ein vil få smertestillande 2 timer før behandling dersom hodepine er ein biverknad, og ein kan justere strømstyke eller redusere antall behandlinger per veke dersom ein får biverknader på hukommelsen.

Av dei som opplever at det blir vanskelegare å hugse eller konsentrere seg, erfarer dei fleste at dette blir betre om lag tre til fire veker etter avslutta behandling. Få opplever långvarige biverknader. Hukommelsesvanskar og forringa kognisjon er det ein sjår oftast. Nokon opplever å gløyme enkeltminner frå fortida, og i sjeldne tilfeller kan ein slite med konsentrasjon og oppmerksomhet over lengre tid.

Når ein skal foreta ei vurdering, er det viktig å ta i betraktning kor inngripande depresjonen er i personens liv satt opp biverknader. Dei personane som mottek ECT har det svært vondt og kan få ei betraktelig økt livskvalitet ved å minske sine depressive symptomar. Samstundes kan det vere sårt å vite at ein kan oppleve biverknader.

Kva skjer med hjernen?

I ECT-behandling triggar man bevisst eit kontrollert anfall.

Nevronane i hjernen danner eit nettverk, nervebanene, som hjernen bruker til å kommunisere. Det er dette som gjer at du kan tenkje, bevege deg, snakke og føle. Og mykje, mykje meir. Desse kommuniserer med små elektriske signaler kalt synapser.

Eit anfall er altså eit forbigåande auke i hjerneaktivitet. Ein ser at dei elektriske signalene i hjernen fyrar av i mykje høgare frekvens enn vanleg. Det er dette som gjer at man vanlegvis rister i kroppen under eit anfall.

Ved ECT-behandling triggar ein eit slikt anfall ved å kort administrere eit elektrisk støt til hovudet. Strømmen stimulerer nevronane i hjernen som triggar anfallet. Ein ønsker at dette skal pågå mellom 20-60 sekunder, mens pasienten ligg i narkose og ikkje kan kjenne noko.

På lik linje med mykje anna medisin, veit ein ikkje eksakt kva som er virkningsmekanismen til ECT. Hjernen er eit komplisert organ. Det ein trur, er at stigninga i hjerneaktivitet under ECT betrar samspelet mellom ulike prosessar i hjernen.

Det ein kan observere, er at etter anfalla, så øker volumet i hjernen litt. Hjernen blir altså litt større enn tidlegare i ein kort periode. I tillegg kan ein sjå at hjernen har lettare for å endre seg i ein periode etter ECT er gitt.

Slik beveger strømmen seg

Desse illustrasjonane viser det elektriske feltet på hjernen. Ved høgresidig elektrodeplassering (RUL) går strømmen frå den øverste elektroda til den nederste. Dei lyse områda viser kor strømmen hovedsakeleg beveger seg.

Her kan ein sjå det elektriske feltet frå inni hjernen. Dette er datasimuleringar, laga frå ein MR-scan. Det er altså ikkje ein person som faktisk har fått ECT-behandling. Her kan ein sjå korleis strømmen beveger seg frå den øverste elektroda til den nederste. Pilane viser retning, mens fargane viser kor det er mest elektristitet. Mesteparten av elektrisiteten går altså gjennom høgre side av hovudet.

Andres erfaringar med ECT

Når ein skal gjennomgå ein ny type behandling, kan det være informativt å høre kva andre har opplevd. Ein bør likevel merke seg at opplevelsen av ECT-behandling er individuelt og vil variere frå person til person.

Pasienterfaringer

Navnene under er fiktive, men tilbakemeldingane er samla inn frå ekte pasientar som har gjennomgått ECT. Det er henta fram eit utvalg av tilbakemeldinger. Målet er at dette utvalget skal være representativt for dataen som er samla inn. Dei er henta frå ulike kvalitative studier om opplevelsane knytta til ECT-behandling. Trykk på bileta under for å sjå tilbakemeldinger frå ekte pasienter.

> *"Eg var jo litt kviafull de første gangene og etter tre behandlinger då begynte det å lette. Det var bare så fantastisk. Så da så eg frem til neste gang eg skulle inn for eg visste det hjalp meg"*

- Gunn, *52*

> *"Skal du gå rundt å være dårlig, eller altså ha det bra og heller ha litt dårlig hukommelse ... då hadde jeg uansett valgt ECT for når du er deprimert så er det - så unnskyld - jævlig."*

- Roger, *45*

> *"En av de vanligste bivirkningene etter ECT er altså hukommelsestap. I dag må jeg skrive ned for å huske avtaler og annet, men det er ikke problematisk i forhold til å leve med konstant depresjon."*

- Annelise, *57*

"Alt var så rolig, ikke noe stress. De var veldig flinke til å forklare alt som skulle skje, etterpå fikk en rundstykker og drikke"

- Gustav, *27*

"Etter behandlingen var jeg veldig ambivalent. Jeg var ikke frisk, men jeg ble mottakelig for hjelp."

- Caroline, *53*

"Jeg var ikke redd for ECT, for jeg hadde hørt så mye godt om det fra før, men jeg vil ikke ta ECT igjen på grunn av bivirkningene jeg fikk"

- Heidi, *42*

"Det at jeg har fått et høyt antall behandlinger plager meg ikke, og jeg regner med at jeg må få vedlikeholdsbehandling resten av mitt liv. I dag fungerer jeg godt i mellom periodene med ECT-behandling, og med støttesamtaler klarer jeg å være i jobb og fungerer utmerket sosialt."

- Lars, *64*

"Som min psykolog sa: 'Du har fortsatt evnen til å lære'. Så jeg har heldigvis ikke fått Alzheimers, men jeg må gjenta og gjenta og det er ikke nok at jeg må gå den veien en gang til."

- Linda, *37*

"Jeg merket bedringen underveis, det gjorde jeg, jeg vil holde det som et kort i fremtiden hvis jeg blir dårlig, absolutt."

- Anders, *71*

Tilbake til Åse.

Når depresjonen er på sitt verste, kjenner ikkje Åse seg sjølv att.

Det siste året har vore ille. Ho er nedstemt stort sett heile tida og slit med å sove. Ho har vore sjukmeldt frå jobben, og har brukt mykje tid på sofaen i stua. Heilt daglegdagse oppgåver som å lage mat og dusje har tappa ho for energi. Av og til har ho fått irrasjonelle tankar om ting i kvardagen som ho egentlig veit ikkje stemmer. Dette gjer ho redd og fortvila, og familien er bekymra for ho.

Depresjonen er så inngripande i livet hennar at ho ikkje klarer å fungere som mamma for borna sine eller kjæreste for ektemannen. Ho klarar ikkje å finne ei klar årsak til kvifor ho kjenner seg slik, og har mykje dårleg samvit. Av og til tenkjer ho at det ikkje er verdt å leve når ein har det slik.

Den siste månaden har ho vore innlagt. I ein av timane ho har med psykiateren sin, foreslår legen at Åse prøver ei behandling som heiter ECT. ECT står for elektrokonvulsiv terapi, og er ein type nevrostimulerande behandling. Ho fortel at behandlinga er svært effektiv for dei som sliter med tung depresjon. Det er også eit godt alternativ for dei som ikkje toler medisinar eller ikkje har hatt noko effekt av dei, slik som Åse, seier ho.

Behandlinga gjer ikkje vondt, og er ikkje farleg, forklarar ho. Ho fortel at ECT er ei trygg behandling som kan verke skummel, men som hjelper mange.

Behandlinga innebærer at ei kontrollert mengde strøm sendast gjennom hjernen via to elektrodar. Dette skal med vilje trigge eit kort krampeanfall. Alt vil skje medan Åse er under narkose, og ikkje kan kjenne noko. Ho vil få muskelavslappande medisinar slik at anfallet går roleg for seg. Ofte er det einaste ein kan sjå at det rykkar litt i muskulaturen i kroppen, seier legen. Etter nokon minutter vil ho vakne igjen og føle seg trøytt og kanskje litt forvirra. Dette er tydelegvis heilt vanleg og vil gå over.

Takkar ho ja til behandlinga vil ho henvisast til seksjon for ECT på Haukeland Universitetssjukehus. Der vil ho få meir informasjon og kunne spørre om alt ho lurar på. Dersom ho ynskjer det, vil ho kunne bli satt i kontakt med ein med brukarerfaring med ECT. Til kvar time blir ho då bli fulgt av eit av personalet frå sengeposten. Før behandlinga må ho signere eit skriftleg samtykke.

Åse seier ho vil tenkje litt på det, og ringe til familien hennar og høre kva dei syns.

Åse ringer familien sin. Ho forklarer mannen hennar kva ECT er. Ho seier hei til borna, og dei seier dei saknar ho og håper ho kjenner seg betre snart. Etter samtalen sovnar borna på fanget til far. Åse og mannen pratar litt vidare på tekstmelding. Ho bestemmer seg for å prøve ECT.

Legen har forklart at Åse må ta nokre prøver og underskrive samtykke før dei kan starte behandling. Ho forklarer Åse kva ECT går ut på, kor mange som opplever betring, og kva biverknader det er risiko for. Legen ber også om tillatelse til å registrere data om behandlinga underveis som dei kan bruke til forskning. Dette seier Åse går heilt greit.

Legen gjør ein fysisk undersøkelse av Åse. Han tar nokre blodprøver og EKG for å registrere aktiviteten i hjartet. Ho spør om Åse går på nokre medisiner og om ho har noværande eller tidligare sjukdommer. Saman sett bestemmer dei at behandling skal igongsettes dersom prøvane sjår fine ut. Behandlingsløpet begynner om to veker.

Legen forklarer at før kvar enkeltbehandling er det viktig at ho faster frå klokka 24 kvelden før - dette er grunna narkosen ho får. Ho kan ikke ete drops eller tygge tyggegummi, men det går fint at ho drikk vatn inntil to timar før behandling. Før første behandling vil ho få ein briefing om akkurat kva som skal skje. I løpet av timen stiller Åse litt spørsmål og underskriver eit skriftleg samtykke.

Prøvane var fine. Det er to veker seinare og Åse er klar for første behandling. Ho står utanfor inngongen til Haukeland ifølge med eit personale frå sengeposten. Det har krevt mykje av ho å møte opp til timen; ho er utslitt og har vanskeleg for å møte menneske. Ho tykjer det er godt og betryggande å ha personalet med seg.

På seksjon for ECT blir ho møtt av eit team med leger og sjukepleiarar. Ho blir leia inn på eit rom der den ein lege som håndhilsar og introduserer seg. Åse fortel legen at ho ønsker ei grundig innføring i kva som kjem til å skje under behandlinga. Legen fortel at tilstades vil det vere minst fire helsepersonell. Ein lege og ein sjukepleier har ansvar for å administrere sjølve behandlinga til Åse. I tillegg vil det vere ein anestesilege og ein anestesisjukepleiar som har ansvar for narkosen.

Dei kommer til å feste nokre elektroder med tynne ledninger på brystet, armen og hovudet hennar. Desse måler hjarterytmen og elektrisk aktivitet i hjernen. Dei vil ta litt gele på huden der dei held elektrodane mot til hovudet. På slik måte får elektrodane får god kontakt med huda.

Anestesipersonalet vil gje Åse nødvendige medisiner gjennom eit plastrøyr, ei venekanyle, festa til armen hennar. Ho vil få på seg ein oksygenmaske som gjer ho ekstra oksygen under narkosen. Ho kjem ikkje til å kjenne noko som helst etter ho er lagt i narkose.

Legen visar Åse ECT-maskina. Der kan dei justere strømstyrke, og under behandlinga vil han printe ut eit papir som viser hjerne, hjerte og muskelaktivitet under anfallet.

Dette målast gjennom elektrodene festa til hovudet, brystet og armen hennar. På toppen av maskina er det ei klokke, som ein bruker til å måle tid fra muskelavslappande medisin er satt, til ein skal gje behandlinga.

Ho viser også Åse elektrodane som benyttast, og som er kobla til ECT-maskina. Eit støt på opp til 7 sekunder vil gis, som triggar anfallet. Under desse 7 sekunda er det ca 1,5 sek med strøm, da strømmen går i bølger (impuls). Medan anfallet pågår følger dei nøye med på hjertet, pusten og hjerneaktiviteten hennar.

Etter anfallet vil Åse trillast til eit oppvåkningsrom. Det varierer veldig kor fort ein vakner i etterkant. Nokon er vaknen etter kort tid, andre kan sove i ein time. Det avhenger av totalsituasjonen, angstnivå, og om pasienten har sovet om natta før dei kjem.

Når ho vakner vil ho kunne føle seg litt forvirra og kjenne seg veldig trøytt. Nokon vil sitte og passe på dei som er på oppvåkningsrommet. Når Åse kjenner seg litt klarare vil ho kunne bli fulgt inn på oppholdsrommet der ho får servert lunsj.

Legen seier at ho ikkje skal vere aleine dei første 24 timane etter ho har mottatt behandling. Ho skal også ha følge av nokon kver gang ho kjem for å motta behandling. Dette er viktig. Legen anbefaler ho heller ikkje å køyrer bil medan ho mottar behandling eller i dei første vekene etterpå. Når ho føler seg bra nok til å dra kan ho gjere det, saman med personalet frå sengeposten.