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ViPo, A VISUAL ELECTRONIC MEDICAL RECORD PROTOTYPE

An Innovation Project

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ABSTRACT

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Purpose

The purpose of this master thesis is to develop and produce a prototype of an Electronic Medical Record (EMR) that is pro-tuned for optometrists and ophthalmologists. The thesis was carried out as an innovation project for Oulu University of Applied Sciences (OUAS) Clinical Optometry degree program. The prototype aims to unify the information recording, thus minimizing the risks for any contradictions by the next inspector.

Methods

This thesis was carried out as an innovation project from 2022 to 2023. The gathered information was implemented in the process of developing the prototype. The tests for this prototype were chosen considering golden standards for a good eye examination in different countries combined with the visual aspect of the prototype in mind. The prototype was created with Plasmic by two people. Plasmic is a visual, no-code page builder and content management system (CMS) for websites or codebases. An IRB approval was not needed, since the literature was analyzed descriptively selecting suitable themes and contents.

Results

As a result of this thesis four guidelines on a comprehensive vision and eye examination were identified and further analyzed. More information on the framework for a working EMR was collected from globally trusted sources, such PubMed and Cochrane as well as some optometry books. A prototype for a never-before-seen Visual Electronic Medical Record (VEMR) called ViPo was created and playtested. The visual database was developed solely focusing on ease of use, both writing and reading of the records.

Conclusions

Many patient databases rely purely on textboxes. This may lead to misinterpretation, if not filled with care or appropriate language. With ViPo you can see the tests and charts used in the eye examination and interact with the VEMR itself. For example, it is possible to draw the clinical findings directly into ViPo.

Keywords: electronic medical record, electronic health record, patient database, patient security, GDPR, HIPAA, optometry, guidelines

CONTENTS

1   INTRODUCTION

Health records have existed since the beginning of the practice of medicine, for around 4000 years. Paper medical records became a standard documentation for patient history in the early 20th century (years 1900 – 1920). The first electronic health record (EHR) was created in 1972 by the Regenstreif Institute in the United States. When first developed, EHRs had high costs and could not be widely used and were primarily used by government hospitals. As computers became more affordable, EHRs could spread for wider and more global use. This revolutionized the format of EHRs and the whole health care field. (Evans 2016, 48-56; Gillum 2013, 853-856).

Specifically in the field of optometry, there are a lot of tests that require some sort of charts for recording the performance of the patient before a diagnosis can be given. Until this day, many EHRs needed to rely solely on textboxes. Also, when inspecting the eye (anterior or posterior), describing the findings may be found cumbersome, and many professionals use different jargon. By showing the charts and allowing the professional to draw the findings directly in to the EMR, we unify the data recording and minimize any contraindication that may occur by the next inspector.

2   THEORETICAL BACKGROUND

2.1   What is an EHR/EMR?

An electronic health record (EHR) is a digital record of a patient's health information that can be accessed by authorized healthcare professionals. An EHR system is comprehensive, multi-institutional and longitudinal collection of data of a patient's health. An EHR includes not only subject's particular medical history, but also their health history in general. (Hoerbst et al. 2010, 320). An EHR typically includes various components, such as medication management, clinical decision support, and electronic prescribing. EHRs aim to improve healthcare delivery by providing clinicians with accurate and up-to-date information about their patients. Even the patient is regarded as an active partner in their treatment, as they are able to access and manage their health data during the treatment. (Hoerbst et al. 2010, 320).

An electronic medical record (EMR) can be seen as a subtype of an EHR. An EMR refers to an electronic record of a patient's medical history that is created, gathered, and managed by a single care delivery organization (CDO), such as a hospital or a clinic. EMR typically contains information such as medical history, diagnoses, medications, treatment plans, and test results. It is designed to be used within a single healthcare organization and is not easily shared between different healthcare providers. (Garets, et al. 2006; Queen 2021).

An EHR can only be established if the EMRs of the various CDOs have achieved a level that can create and support seamless exchange of information between the community, region, or stakeholders. An EHR contains all of the information in an EMR, as well as additional information such as patient demographics, laboratory test results, radiology images, and immunization records. EHRs are designed to improve coordination of care between different healthcare providers, reduce medical errors, and improve patient outcomes. (Garets et al. 2006; Queen 2021).

A fully working EHR system requires a combination of hardware, software, data management, security, and user support components, as well as interoperability with other devices or computers to share the information

quickly but securely. A comprehensive list of criteria for a fully working EHR system, as suggested by Garets, D. et al (2006), Hoerbst, A. et al (2010), Karla, D. (2006) and Queen, J.T. (2021):

1. **Data Storage and Management**: The EHR must have a secure and reliable database that can store patient information, everything from patient id and contact information to medical history, test results, and other healthcare-related data.

2. **Interoperability**: The EHR must be able to share data with other healthcare systems and providers, including hospitals, clinics, laboratories, and pharmacies.

3. **User Interface**: The EHR must have a user-friendly interface that allows healthcare providers to easily access and navigate patient information and generate reports, without negatively affecting workflow.

4. **Clinical Decision Support**: The EHR should have tools that can provide clinical decision support to healthcare providers, including alerts, reminders, and best-practice guidelines.

5. **Security and Privacy**: The EHR must comply with data security and privacy regulations, such as GDPR (General Data Protection Regulation) in the EU, HIPAA (The Health Insurance Portability and Accountability Act of 1996) in the USA or Regulation on the electronic processing of customer's social and health care data 784/2021 (Laki sosiaali- ja terveydenhuollon asiakastietojen sähköisestä käsittelystä 784/2021) in Finland. The EHR must have appropriate safeguards in place to protect patient data from unauthorized access or disclosure.

6. **Integration with other systems**: The EHR should be able to integrate with other healthcare IT systems, such as billing and scheduling systems, to streamline workflows and improve efficiency.

7. **Mobile access**: The EHR should be accessible via mobile devices, allowing healthcare providers to access patient information and provide care remotely.

8. **Patient access**: The EHR should provide patients with secure access to their own health information, allowing them to review their medical records, schedule appointments, and communicate with their healthcare providers.

9. **Analytics and Reporting**: The EHR should provide robust analytics and reporting capabilities, allowing healthcare organizations to track clinical outcomes, identify trends, and monitor performance.

10. **Customization and Scalability**: The EHR should be flexible and customizable to meet the unique needs of different healthcare organizations, and should be able to scale to accommodate changes in patient volume and clinical workflows over time.

An EMR system is more local and hospital-specific. An EMR also requires a combination of hardware, software, data management, security, and user support components, as well as interoperability with imaging devices, such as OCT (Optical Coherence Tomography). See the list below for an initial set of differences between an EHR and an EMR as suggested by Garets, D. et al. (2006), Poissant L. et al. (2005), Rector, A.L. et al. (1991), and Queen, J.T. (2021):

1. **Scope**: An EMR is a digital version of a patient's medical record that is created and stored by a single healthcare provider or facility, while an EHR is a comprehensive digital record of a patient's health information that is created and shared across multiple healthcare providers and facilities.

2. **Interoperability**: While EMRs are generally designed to be used within a single CDO, EHRs are designed to be interoperable and share data across multiple healthcare organizations.

3. **Information Sharing**: EMRs are generally used to document patient care within a single healthcare facility and are not intended to be shared with other healthcare providers. EHRs, on the other hand, are designed to facilitate information sharing between healthcare providers to improve care coordination.

4. **Patient Access**: EMRs typically do not provide patients with direct access to their own health information, while EHRs are designed to give patients secure access to their own medical records.

5. **Functionality**: EHRs typically offer a broader range of functionality than EMRs, including clinical decision support tools, patient engagement features, and analytics and reporting capabilities.

2.1.1   Benefits of an EHR/EMR

All electronic patient databases have tremendous potential to provide substantial benefits to the physicians, clinic practices and healthcare organizations. When implemented correctly, these systems improve workflow, quality of care and patient safety. Overall EHRs have many more benefits than drawbacks. (Hoover 2016).

Basic benefits of an EHR/EMR include elimination of poor handwriting. Since the physician is forced to use a keyboard for typing, the next physician (or the patient) inspecting the data can effortlessly read exactly what has been written into the EHR/EMR. (Hoover 2016, 21-22; Menachemi et al. 2011, 47-53). When implemented correctly, EHRs and EMRs are proven to improve quality of life properties in at least following

areas: care effectiveness, prescribing support, disease management, clinical documentation, workflow, job satisfaction, increased revenue, averted costs, and even patient-physician interaction. (Menachemi et al. 2011; Queen 2021).

In practice, various factors may result in insufficient care-effectiveness that do not adhere the best practice guidelines. Factors might include lack of time during the patient visit, clinicians not knowing the guidelines, or clinicians not realizing that a guideline applies to a given patient. It is in EHR systems' best interests to overcome these issues. (Menachemi et al. 2011). For example, applying a computerized reminder into an EHR increased the use of influenza and pneumococcal vaccinations for hospitalized patients from 0% to 35% and 50% respectively. (Dexter et al. 2001, 965-970). A similar study (outpatient setting) showed that among rheumatology patients that took immunosuppressants, computerized reminders were associated with improved influenza and pneumococcal vaccination rates. (Ledwich et al. 2009, 1505-1510).

Researchers have also noted that EHRs can improve patient care in preventive services as well. A computerized alert increased the use of anticoagulation prophylaxis by 19%. This translated into a 41% reduced risk of deep vein thrombosis or pulmonary embolism. (Kucher et al. 2005, 969-977).

With EHRs and EMRs healthcare providers can quickly access a patient's complete medical history, reducing the risk of prescribing medications that could have adverse effects when combined with other drugs the patient is already taking. (Menachemi et al. 2011; Lau et al. 2012). In a vastly cited study, researchers found out that a computerized physician order entry (CPOE) reduced serious medication errors by 55%. (Bates 1998). Less than a year later, the same team discovered that adding a clinical decision support tool and combining it with a CPOE resulted in an 86% reduction in medication errors. (Bates 1999).

Sharing patient information electronically eliminates the need for paper-based records and ensures that all healthcare providers involved in a patient's care have access to the same up-to-date information. When less mistakes happen, also less money goes into correcting those mistakes or to the consequences the mistakes caused. Electronic databases also reduce administrative burdens, as they eliminate the need for manual data entry and paper-based record-keeping, which frees up time for healthcare providers to focus on patient care. (Ilie et al. 2009; Lau et al. 2012).

Organizational outcomes included increased revenue, averted costs and other benefits such as increased job satisfaction among physicians, improved legal and regulatory compliance, and improved ability to conduct research. (Menachemi et al. 2011). EHRs store enormous amounts of data readily available. When optimized correctly, these EHRs are invaluable for their ability to improve quality and speed of care. The physicians are able to treat more patients per day, when they don't have to pay extra attention to figuring out how to use the EHR/EMR. (Hoover 2016).

Lau, F. et al. (2012) systematic review suggests that there is a 51% chance that an EMR can improve office practice. 30% of the time there may not be any difference and only 19% may lead to negative consequences. (Lau et al. 2012). According to research conducted by Queen, JT. (2021), up to 74.02% of the participants either strongly agree or agree that EHRs and EMRs have saved them time. 78.74% of the participants either strongly agree or agree that the electronic platforms improved the efficiency of their health care experiences. (Queen 2021).

Yaron Bar-Dayan and colleagues discovered that further development of an already existing EHR may also be beneficial: a case study of an Israeli hospital that implemented an application that had a list of preferred specialty care providers. The 4-year study shows that the costs declined by 4.08% from year 2005 to 2006, by 4.96% from year 2006 to 2007, and by 2.99% from year 2007 to 2008. The cost of developing the application in the already existing EHR cost only 6.1% of the savings that the application had accumulated in its first year after development. (Bar-Dayan et al. 2013).

EHR/EMR technology has also shown its dominance in the times of uncertainty, like today's COVID-19 pandemic. These databases can be accessed, viewed and consulted effortlessly despite a potential decrease in face-to-face communication. (Queen 2021).

2.1.2 Drawbacks of an EHR/EMR

Unfortunately, EHRs as well as EMRs can also lead to workflow disruptions and inefficiencies, particularly when the EHR or EMR is not designed or implemented effectively. The communication between the care providing specialists must be top-notch. Multiple users may enter or access patient information, and communication mistakes can occur, leading to inaccurate or incomplete records. Furthermore, healthcare

providers may misinterpret the data, leading to incorrect diagnoses or treatments. For instance, if one physician fails to document a critical piece of information, such as medication allergies, other physicians may not be aware of this and may inadvertently prescribe a medication that could lead to a life-threatening reaction. To mitigate these risks and minimize workflow disruptions, healthcare organizations need to implement comprehensive training programs for their staff, emphasizing the importance of accuracy and precision in data entry and interpretation. (de Ruiter et al. 2016; Queen 2021).

As well as any other electronic database, EHRs and EMRs are vulnerable to security breaches. A security breach happens when confidential health information is made available to others without the consent or authorization of the affected individual. This can happen by someone working inside the CDO or by a hacker. EHRs and EMRs must be made more secure with measures such as cloud storage, password protection, encryption, firewalls, antivirus software, intrusion detection and even two-factor authentication. All these measures increase the cost of the EHR/EMR. (Nayer et al. 2015).

Healthcare providers and organizations must take a critical and reflective approach to the use of EHRs/EMRs, carefully considering the potential benefits and drawbacks of these technologies, and ensuring that they are used in ways that are consistent with the values and goals of the desired healthcare. By doing so, healthcare providers and organizations can ensure that EMRs are used in ways that promote high-quality, patient-centered care, while also addressing the ethical and practical challenges associated with these technologies. (de Ruiter et al. 2016; Queen 2021).

2.1.3   Blockchain Technology

Traditional EHR systems rely on a centralized database that is controlled by a single entity, such as a hospital or healthcare provider. In contrast, a blockchain EHR allows patient data to be distributed across a decentralized network of computers. Blockchains hold batches of transactions that are hashed, therefore providing extra security, anonymity and integrity of data with no third-party intervention. Blockchains are managed in peer-to-peer network, making it more difficult for hackers to compromise or manipulate the data. Key features for blockchain technology are decentralization, data transparency, security and privacy. (Mohammed et al. 2021; Shahnaz et al. 2019).

In a blockchain EHR, patient data is stored in blocks, which are linked together in a chronological and immutable chain. Each block contains a record of a patient's medical data, such as their diagnosis, treatment history, lab results, and medications. This means that the patient's data is an entity itself, and it could be read, processed and analyzed by authorized parties anywhere. As for now, a new record must be created to another CDO's EHR, would the patient want to start treatment elsewhere. The data is encrypted, making it only accessible to authorized parties with the proper decryption key. (Shahnaz et al. 2019).

However, as the blockchain technology is still in its initial state, there are challenges yet to overcome. The way blockchain technology works is understood by very few people, and is yet to be standardized. However, Mohammed, S., et al. (2021) proposes that blockchain technology would be GDPR- and HIPAA-friendly due to its superior security. (Mohammed et al. 2021).

2.2   Privacy Policies

The General Data Protection Regulation (GDPR) and the Health Insurance Portability Accountability Act (HIPAA) are two different sets of regulations that aim to protect the privacy and security of personal information. While both regulations have similar goals, they differ in their approach and scope.

2.2.1   GDPR

GDPR is a comprehensive data privacy law that was introduced by the European Union in 2018. Its main aim is to protect the privacy and personal data of individuals in the EU by regulating the way organizations (or 'controllers') collect, process, and store their data. 'Controller' is a natural or legal person, public authority, agency or other body that is part of processing personal data. 'Processing' means any operation that is performed on personal data, whether or not by automated means. The right to privacy is explicit in the Charter of Fundamental Rights. (Pereira et al. 2011; Voigt et al. 2017, 9-26).

GDPR applies to all organizations that process personal data of individuals residing in the EU, regardless of where the organization is based. GDPR provides individuals with a range of rights, including the right to access, correct, modify, delete, and restrict the processing of their personal data. GDPR also requires organizations to implement technical and organizational measures to ensure the security and confidentiality of personal data. EHRs and EMRs include types of personal data, such as medical history, diagnoses, treatment plans, medications, and lab results. This type of data is considered sensitive personal data under GDPR and is subject to strict regulation. Hence GDPR has set a list of requirements for organizations that utilize databases such as EHRs and EMRs: (Voigt et al. 2017).

1. **Records of Processing Activities**: Processors and controllers had to implement records of their processing activities, such as collecting, recording, organizing, structuring, storing or erasing data. The purpose of maintaining these records is to ensure transparency and accountability in data processing activities, as GDPR requires. In the event of an inspection by a supervisory authority, the records of processing activities can be used to provide evidence that data processing activities are being carried out in compliance with the GDPR.

2. **Appointing a Data Protection Officer (DPO)**: Organizations that process or handle large amounts of personal data or sensitive data were required to appoint a DPO to ensure compliance with GDPR. Any DPO must be designated based on their expertise and professional qualities in order to ensure that GDPR can be successfully followed.

3. **Conducting a Data Protection Impact Assessment (DPIA)**: Organizations that process personal data on a large scale or process special categories of personal data were required to conduct a DPIA to identify and mitigate any potential data protection risks. An example of this could be an intended processing activity, when using new technologies.

4. **Updating privacy policies**: Organizations had to update their privacy policies to ensure they were transparent about their data processing practices, and that individuals had clear information about how their personal data was being used.

5. **Obtaining consent**: Organizations had to obtain explicit consent from individuals before processing their personal data. The consent must be clearly stated, and all the options and rights of the patient must be shown to the patient.

6. **Implementing technical and organizational measures**: Organizations had to implement appropriate technical and organizational measures to ensure the security of personal data, such as encryption and access controls.

7. **Reporting data breaches**: Organizations were required to report any data breaches to the relevant supervisory authority within 72 hours of becoming aware of the breach.

8. **Ensuring compliance by third-party processors**: Organizations were responsible for ensuring that any third-party processors they worked with were also compliant with GDPR.

9. **Appointment of a representative by non-EU entities**: All entities that fall within the scope of the GDPR, must have an EU-located representative.

10. **Codes of conduct and certifications**: Codes of Conduct specify the obligations the GDPR requires and Certifications will prove compliance of the certified activities with the GDPR. Entities may use these instruments as safeguards for third country data transfers.

One of the key principles of GDPR is the principle of data minimization. This means that controllers should only collect and process personal data that is necessary for the purpose for which it is being processed. In the case of EHRs and EMRs, this means that controllers should only collect and process the minimum amount of personal health information necessary for patient care. Organizations must also ensure that personal data is accurate, up-to-date, and not kept for longer than necessary. (Voigt et al. 2017, 9-26).

While anonymization requires the complete deletion of personal data, pseudonymization is a GDPR-friendly technique to ensure patient safety. Pseudonymization is the process of replacing all personal data with random pseudonyms. The mapping between pseudonyms and personal data must be stored separately and securely. An example of pseudonymization is randomly generating unique identification codes, such as patient numbers in this case. (Mohammed et al. 2021).

GDPR has significant implications for the non-complying collection, processing, and storage of personal health information in EHRs and EMRs. As Mohammed, S., et al (2021) reviewed, security and privacy are the most valued priorities in GDPR. A long-lasting solution for this could be blockchain-based EHR systems. As blockchain EHRs allow several benefits compared to their traditional counterparts, (see chapter 2.1.3 "Blockchain technology") they would perfectly comply with GDPR as well as HIPAA. (Mohammed et al. 2021).

In conclusion, healthcare organizations must ensure that they are compliant with GDPR to protect the privacy and personal data of their patients. This includes obtaining explicit consent, implementing appropriate technical and organizational measures, minimizing the amount of personal data collected, and ensuring the

security of personal data. Organizations must be prepared for anything when sharing sensitive information. The organizations must have procedures in place for handling data breaches and sharing personal data with third parties. (Mohammed et al. 2021; Voigt et al. 2017).

2.2.2 HIPAA

HIPAA applies specifically to protected health information (PHI) in the United States and sets standards for how healthcare providers, health plans, and their business associates handle and protect PHI. The American legislation is a specific law, which creates the federal law followed by the United States. The right to privacy is not explicit in the Constitution. HIPAA requires covered entities to implement technical, administrative, and physical safeguards to protect PHI, and also grants individuals certain rights over their PHI. There are several major differences between GDPR and HIPAA: (Cohen et al. 2018; The HIPAA Journal, 2022; Pereira et al. 2011; Voigt et al. 2017).

1. **Scope**: GDPR covers all personal data processed by businesses operating within the EU, while HIPAA only covers PHI in the context of healthcare providers, health plans, and healthcare clearinghouses in the US. This means that GDPR has a broader scope than HIPAA.

2. **Definition of personal information**: GDPR defines personal information broadly to include any information that can directly or indirectly identify an individual, while HIPAA focuses specifically on PHI, which includes information related to an individual's health status or health care services.

3. **Consent**: GDPR requires businesses to obtain explicit consent from individuals before processing their personal data, whereas HIPAA only requires that covered entities obtain written consent or "reasonable assurances" for certain types of disclosures. This means that GDPR places a greater emphasis on obtaining informed consent from individuals.

4. **Penalties**: GDPR imposes significantly higher penalties for non-compliance than HIPAA. The maximum penalty for GDPR violations is up to 2% of a company's global revenue or €10 million (whichever is greater), while HIPAA's maximum penalty is $1.9 million per year. However, HIPAA violations are handled on case-by-case basis, and the penalty might be as little as $127.

5. **Data Subject Rights**: HIPAA is a US law that applies to healthcare organizations and their business associates. Its primary goal is to protect the privacy and security of individuals' health information, including medical records, billing information, and other types of PHI. HIPAA grants individuals the

right to access and control their PHI and requires healthcare organizations to implement safeguards to protect the confidentiality, integrity, and availability of PHI. In terms of granting control over PHI and personal data, both HIPAA and GDPR provide individuals with similar rights to access, control, and protect their information. However, the specific requirements and procedures may differ depending on the law, jurisdiction, and the type of information involved. Ultimately, the level of control and protection provided by HIPAA and GDPR may depend on the specific circumstances and context in which the information is being collected, processed, and stored.

Overall, while there are some similarities between GDPR and HIPAA, the two laws have different objectives, scopes, and requirements, and organizations that handle personal data or protected health information need to be aware of the differences and comply with both laws where applicable. (Pereira et al. 2011, 567-570).

2.2.3 Supervisory Authorities

Supervisory authorities are independent, impartial, and adequately resourced public bodies responsible for ensuring that businesses and organizations comply with the GDPR or HIPAA. They have the power to investigate, fine, and take legal action against businesses and organizations that breach the GDPR/HIPAA. (Pereira et al. 2011; Voigt et al. 2017, 189-199).

The European legislation is a profound law, implemented by supervision. The GDPR establishes a single supervisory authority for each EU member state, which is responsible for overseeing compliance with the GDPR within its jurisdiction. The GDPR also requires supervisory authorities to work together closely and to share information to ensure consistent enforcement of the GDPR across the EU. (Voigt et al. 2017, 189-199).

Under the GDPR, supervisory authorities have a range of enforcement powers. These include the power to carry out on-site inspections and audits, to request information from businesses and organizations, and to order the suspension or limitation of data processing activities. Supervisory authorities can also impose fines for breaches of the GDPR, with fines of up to 2% of a company's global annual revenue or €10 million, whichever is higher. In addition to their enforcement powers, supervisory authorities also play a role in

promoting compliance with the GDPR. They provide guidance and advice to businesses and organizations on how to comply with the regulation and help to raise awareness of the GDPR among individuals and businesses. (Voigt et al. 2017, 189-199).

The GDPR places significant responsibilities on supervisory authorities to ensure compliance with the regulation. These authorities are tasked with investigating complaints and breaches, imposing fines and other penalties, and promoting compliance with the GDPR. They are required to be independent, impartial, and adequately resourced to carry out their tasks effectively, and they must work together closely to ensure consistent enforcement of the GDPR across the EU. (Voigt et al. 2017, 189-199).

In the United States, there are several federal agencies that serve as supervisory authorities for different aspects of privacy and data protection. For example, the Office for Civil Rights (OCR) within the Department of Health and Human Services (HHS) is responsible for enforcing HIPAA's Privacy and Security Rules, which govern the privacy and security of patients' health information. The Federal Trade Commission (FTC) is another important agency that enforces consumer privacy laws, such as the Children's Online Privacy Protection Act (COPPA) and the Fair Credit Reporting Act (FCRA). (Pereira et al. 2011, 567-570).

HIPAA does not require organizations to obtain certification of compliance, but it does establish regulatory oversight by the US Department of Health and Human Services (HHS) Office for Civil Rights (OCR). The OCR is responsible for enforcing HIPAA's privacy and security rules, investigating complaints of non-compliance, and imposing penalties on organizations that violate HIPAA regulations. (Pereira et al. 2011, 567-570).

The supervisory authorities play a critical role in ensuring compliance with HIPAA regulations by conducting audits and investigations, responding to complaints, and imposing penalties for non-compliance. The OCR has the power to conduct audits of covered entities and their business associates to ensure that they are complying with HIPAA's privacy and security rules. The OCR also investigates complaints of non-compliance and can impose civil monetary penalties on organizations that violate HIPAA regulations. (Pereira et al. 2011, 567-570).

While HIPAA does not require certification of compliance, the OCR has emphasized the importance of self-assessment and documentation of compliance efforts. Covered entities and business associates are expected to conduct regular risk assessments, implement appropriate safeguards to protect PHI, and maintain documentation of their compliance efforts. The OCR may consider an organization's compliance efforts when investigating a complaint or assessing penalties for non-compliance. (Pereira et al. 2011, 567-570).

The compliance to the GDPR/HIPAA must be proven when requested upon. The supervisory authorities may request the organization to prove the compliance under the accountability principle at any given time. This obligation explicitly refers to the principles of lawfulness and transparency of processing personal data. Having an EHR or EMR with records of processing activities will be very helpful when proving the compliance. Details on the data flow should also be included in the records. (Voigt et al. 2017, 189-199).

2.3   A Good Eye and Vision Examination Methodology

For the sake of this Master thesis, we are going to analyze some guidelines on how to achieve a comprehensive and an ethical vision and eye examination. (See chapter 3.5.2 "Development of the Prototype). The guidelines for a good eye and vision examination methodology vary from country to country, although some continent-wide agreements have been made.

1. **The Finnish Ethical Board of Optometry (OEN)** guidelines for Finnish optometrists on the good eye and vision examination methodology (Hyvä optometristin tutkimuskäytäntö -ohjeistus 2019).
2. **American Optometric Association (AOA)** evidence-based clinical practice guidelines on the adult eye and vision examination (American Optometric Association 2015).
3. **The European Council of Optometry and Optics (ECOO)** guidelines for optometric and optical services in Europe (ECOO Guidelines for Optometric and Optical Services in Europe EXECUTIVE SUMMARY 2013).
4. **The College of Optometrists (The professional body of optometry in the United Kingdom)** – The routine eye examination ('sight test') (The routine eye examination ('sight test') - College of Optometrists s.a.).

While there may be some differences in specific details, all of these guidelines agree on the following general principles related to optometry and vision care:

- The importance of providing high-quality and evidence-based care to patients.
- The need for a comprehensive and systematic approach to conducting eye and vision examinations, which includes taking a patient's history, performing various tests and measurements, and making a diagnosis or referral as necessary.
- The importance of communication and informed consent with patients, including discussing findings and recommendations, and involving them in decisions about their care.
- The importance of ongoing professional development and keeping up-to-date with the latest research and best practices in the field.
- The need to adhere to ethical standards and guidelines, including maintaining patient confidentiality and respecting patient autonomy.

It is worth noting that all of the four guidelines recommend dilating the pupils to fully evaluate the health of the eye. However, as of 2023, optometrists have very different roles globally. For example, in the US optometrists are authorized to diagnose and manage common eye diseases and disorders such as glaucoma, macular degeneration, and diabetic retinopathy. In many states, optometrists are also authorized to use diagnostic and therapeutic pharmaceutical agents to treat certain eye conditions, such as infections or inflammation, as well as prescribe oral medications for some eye-related conditions. (American Optometric Association 2015).

This is not yet the case in most of the European countries, like Finland. In Finland the optometrist can only 'suspect' the patient having an eye disease and must then refer the patient to an ophthalmologist. A Finnish regulation on Health care professionals 564/1994, 16 § (Asetus terveydenhuollon ammattihenkilöistä 564/1994 – Ajantasainen lainsäädäntö – FINLEX ® s.a.). states that optometrists and opticians are not allowed to independently prescribe glasses to:

1. A child under the age of eight
2. A person who has previously had eye surgery on the eyeball
3. A person who appears to have an eye disease
4. A person whose visual acuity will not become normal with eyeglasses

Ultimately, the decision to dilate pupils during an eye exam should be made based on the individual patient's needs and the professional judgment of the optometrist.

2.3.1   List of Required Tests

It's important to note that the specific tests and procedures performed during an eye exam vary depending on the individual patient's needs and the professional judgment of the optometrist or ophthalmologist. The guidelines mentioned above provide a general framework for conducting a comprehensive eye exam, but the specific tests and procedures used may differ based on the clinical situation. Usually, the tests should be done in order "from anterior to posterior".

1. **Depth perception testing** - This test checks how well the eyes work together to perceive depth and three-dimensional space.
2. **Color vision testing** - This test checks whether there are any color vision deficiencies.
3. **Eye muscle movement test** - This test assesses how well the eyes move in different directions.
4. **Visual acuity & refraction test** - This test measures the sharpness of the vision at various distances and whether prescription glasses or contact lenses are needed.
5. **Eye pressure test (tonometry)** - This test measures the intra ocular pressure (IOP) to check for signs of glaucoma.
6. **Slit-lamp examination** - This is an examination of the front structures of the eye, including the cornea, iris, and lens.
7. **Pupil dilation** - This involves using certain eye drops to dilate pupils so that the optometrist can examine the internal structures of the eyes.
8. **Retinal examination** - This involves examining the inside of the eye, including the retina, blood vessels, and optic nerve, typically using specialized instruments such as an ophthalmoscope or a fundus camera.

3 THE PURPOSE, OBJECTIVES AND TASKS OF THE RESEARCH DEVELOPMENT WORK AND OF THE DIFFERENT STAGES

3.1 The Purpose of the Study Statement

The purpose of this master thesis was to develop and produce a prototype of a Visual Electronic Medical Record (VEMR) that is pro-tuned for optometrists and ophthalmologists.

3.2 Statement of the Research Question

What constitutes the basic components of the framework for creating a new EMR to maximize workflow for eye care practitioners?

3.3 Summary Description of the Experimental Design

This innovation project was a development process of an electronic medical record, consisting a literature review composed as background information for this project. OUAS wanted this prototype for test use for its master optometry students. The tests for this prototype were chosen considering golden standards for a good eye examination in different countries. Wanting to minimize negative workflow, led to the idea of a more visually interactive EMR.

The early production of ViPo started in July 2022. The Version 1.000 was complete in July 2023. This thesis was written between January 2023 and September 2023. Theoretical information was collected from globally trusted databases, such as PubMed, as well as some optometry textbooks.

Theoretical background was made to introduce the basics as well as pros and cons of EMRs and what should be included in a comprehensive vision and eye examination. This is to show how the required tests were integrated to the prototype produced. Database keywords included: electronic medical record, electronic health record, patient database, patient security, optometry, guidelines.

3.4 Study Aims

The first aim of the study was to conduct literature research on the subject of EMRs.

The second aim of the study was to define and create a new innovative EMR.

The third aim of the study was to organize a playtest for the prototype to get constructive feedback.

3.5 Methodology

3.5.1 Literature Search and Selection

Before starting the development process, it is crucial to have a clear understanding of the requirements and goals of the EMR system. This involves gathering feedback from healthcare professionals, understanding regulatory compliance requirements, and assessing the budget and timeline for the project. The primary search process for basics for an EHR/EMR was performed from January 2023 to April 2023.

An IRB approval was not needed, since the literature was analyzed descriptively selecting suitable themes and contents.

3.5.2 Development of the Prototype

The early development for ViPo began July 2022, with me drawing simple schematics on Microsoft Paint (see chapter 8.1 Appendix 1 – The Early Schematics). As an optometrist, I felt a duty to create a better EMR, pro-tuned to optometrists/ophthalmologists. Increasing workflow would benefit all – the specialist, the patient and the company.

July 2022, I introduced this project to my childhood friend Juha Eskonen, a Master of Science in Computer Science. He immediately found this project fascinating and agreed to help me with programming.

Plasmic was chosen as a design platform for the prototype because of Juha Eskonen recommended it. Plasmic is a visual, no-code page builder and content management system (CMS) for websites and codebases. Plasmic allowed us to split the prototype designing work in half, as with some self-learning I could design the visual aspects of the prototype and Juha Eskonen could focus on programming and coding the interactivity of the VEMR. Juha and I had to communicate frequently as I had little to no information on what was possible to create within Plasmic, and Juha had no information on how the optometric tests would be performed and recorded.

Plasmic uses TypeScript as programming language. React JavaScript library was selected as framework due to its popularity and previous user experience. Both TypeScript and React are commonly used in web-based frontend user interfaces and projects alike, such as this VEMR. Plasmic requires data to be sent to a different component, when designing an interactive feature. Redux state management library was used to create interactive features for the prototype, as it has an ability to facilitate communication and sharing of data across components.

3.5.3 Playtesting of the Prototype

The playtest was executed in August 2023, after finishing the initial prototype (Version 1.000) in July 2023. The playtest was generated in real-life eye hospital and real-life optical store settings. ViPo was put to an additional screen, while optometrists and ophthalmologists did their normal work. While recording the data to the usual EMR, they also viewed the prototype on the separate screen, and imagined putting the same data in. Instructions for the prototype were not given to test the workflow nature of the VEMR. The questionnaire had a checkbox for the title of the test user as well as two questions: "What did you like about the VEMR?" and "How would you improve the VEMR?". (See chapter 8.2 "Appendix 2 – The Questionnaire"). The feedback from the playtest revealed some major points that must be taken into consideration with this kind of EMR.

4   IMPLEMENTATION OF THE RESEARCH AND DEVELOPMENT WORK

4.1   Specific Aim 1, Literature Research

The first specific aim was to conduct literature research on the subject of EMRs, as well as some guidelines on how to do a good vision and eye examination.

4.1.1   Methods

Literature that thoroughly deals with EMRs and EHRs was conducted to better understand the subject. Also, global guidelines for good eye and vision examination methodology were observed. Globally trusted databases, such as PubMed and Cochrane, as well as some optometry textbooks, were used. Keywords included: electronic medical record, electronic health record, patient database, patient security, GDPR, HIPAA, optometry, guidelines. Searches were made in English without date restrictions.

4.1.2   Results

This resulted in a deeper analysis of following subjects:

1. Basics of an electronic patient database
2. Requirements for creating a fully working EHR/EMR
3. Patients' rights and security and guidelines such as GDPR and HIPAA
4. Guidelines for good eye and vision examination methodology in countries like Finland, USA and UK.

The optometric tests implemented into the prototype were chosen with the good eye and vision examination methodology in mind. (See chapter 2.3 "A Good Eye and Vision Examination Methodology"). The list below shows how each test was implemented:

1. **Depth perception testing** – Interactive Lang I & II, TNO and Titmus FLY -tests.

2. **Color vision testing** – Ishihara

3. **Eye muscle movement test** – Interactive broad H test and near point convergence (NPC) test.

4. **Visual acuity & refraction test** – Open textboxes for spherical power, cylinder, axis, prism, base of the prism, near add and visual acuity. Patient's visual acuity is shown in a chart, where you can easily observe visual acuity progression.

5. **Eye pressure test (tonometry)** – Open textboxes for measuring IOP. Patient's IOP is shown in a chart, where you can easily observe IOP progression.

6. **Slit-lamp examination** – An anterior view of eyes is shown in an interactive picture. The optometrist/ophthalmologist can draw the findings directly into the picture.

7. **Pupil dilation** – A tab dedicated to posterior eye inspection.

8. **Retinal examination** – Retinas of eyes are shown in an interactive picture. The optometrist/ophthalmologist can draw the findings directly into the picture.

4.1.3   Discussion

As the literature research data suggests, there are way more positives than negatives to having an EHR and/or EMR. It's important however, that the EHR/EMR is designed with its sole purpose and working environment in mind.

For clinicians, EHRs and EMRs provide quick and easy access to patient data, including medical history, diagnoses, medication history, lab results, and imaging studies. EHRs and EMRs also help clinicians make better decisions about patient care by providing alerts and reminders for preventive care, drug interactions, and allergy warnings. In addition, EHRs and EMRs can improve communication and coordination among healthcare providers, reducing the likelihood of medical errors and improving patient outcomes.

For patients, EHRs and EMRs offer several benefits, including better access to their medical records, improved patient safety, and more personalized care. Patients can access their medical records and communicate with their healthcare providers through secure patient portals, which can improve patient

engagement and satisfaction. Patients can also participate more actively in their care by reviewing their medical records, tracking their progress, and setting goals with their healthcare providers.

For healthcare organizations, EHRs and EMRs can improve efficiency, reduce costs, and improve patient outcomes. EHRs and EMRs can streamline administrative processes, reduce medical errors, and improve clinical outcomes. In addition, EHRs and EMRs can facilitate population health management and clinical research, helping organizations identify and address health disparities and improve the quality of care for patients.

Despite these benefits, EHRs and EMRs also pose several challenges, including interoperability and data security. EHRs and EMRs from different vendors may not be compatible with each other, making it difficult to share patient data across different healthcare systems. EHRs and EMRs also raise concerns about data security and privacy, as sensitive patient information is stored electronically and may be vulnerable to cyber-attacks. The most prevalent challenge remains user adoption. Poorly designed software combined with little to no training leads to devastating job satisfactions results, slows down clinicians working cycle, and hence affecting the revenue of the whole healthcare organization. The healthcare organizations top priority should be an effective EHR/EMR, since it affects both directly and indirectly to the revenue.

4.2   Specific Aim 2, Developing the Prototype

The second specific aim of the study was to use newly learnt information to create a new innovative tool for eye care practitioners to increase workflow.

4.2.1   Methods

In the theoretical background the basics for an EHR/EMR were observed, as well as good eye and vision examination methodology. This information alongside with user experience were used to create the interface for the prototype.

4.2.2 Results

As a result, a new visual electronic medical record called ViPo (Fin. Visuaalinen Potilasrekisteri; Eng. Visual Electronic Medical Record) was developed and produced alongside with instructions. While aiming for a purely intuitive and workflow enhancing experience with the prototype, instructions may be needed and they fit in this chapter of the Master thesis. Pages 29-40 show the user interface of ViPo as well as how to operate each test. Figures 1-4 introduce the user interface, and figures 5-23 have test specific instructions. Figures 24 and 25 show how to conclude and schedule the next visit.

Figure 1: This screen is first shown when the application is launched. Here you can search for an existing patient by either their social security number or by anonymous patient number. If the number presented is not recognized, a new patient will be added to the database.
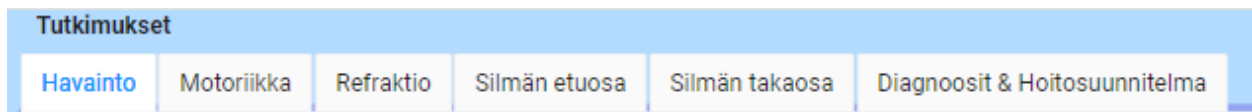
Figure 2: This is the navigation bar. By clicking different tabs, different tests are shown. The tests have been categorized "from anterior to posterior" according to good ethical eye examination methodology.

Figure 3: When viewing patient data, these boxes are always visible, regardless of the tab. Here you fill in the most crucial information about the patient, such as ID, why they are in your office right now and any allergies or contraindications. With the blue arrows you can browse between previous and next visits.

Figure 4: "Other observations". This text box is met at the very bottom of every tab. This text box is meant for any add-on information that occurred during the tests. Such as: "Patient constantly tilts their head to the right", or: "Near vision test distance 25 cm".

Figure 5: Lang stereo test: Click the image(s) the patient saw. The correct disparity is shown below in seconds of arc (for example 400").

Figure 6: Titmus FLY test: Choose whether the patient grabbed the fly's wings or not (defect / no defect).
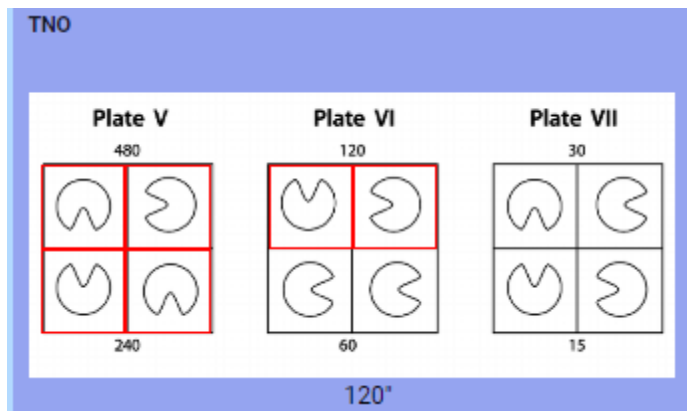
Figure 7: TNO stereo test: Click the image(s) the patient saw. The correct disparity is shown below in seconds of arc (for example 120").
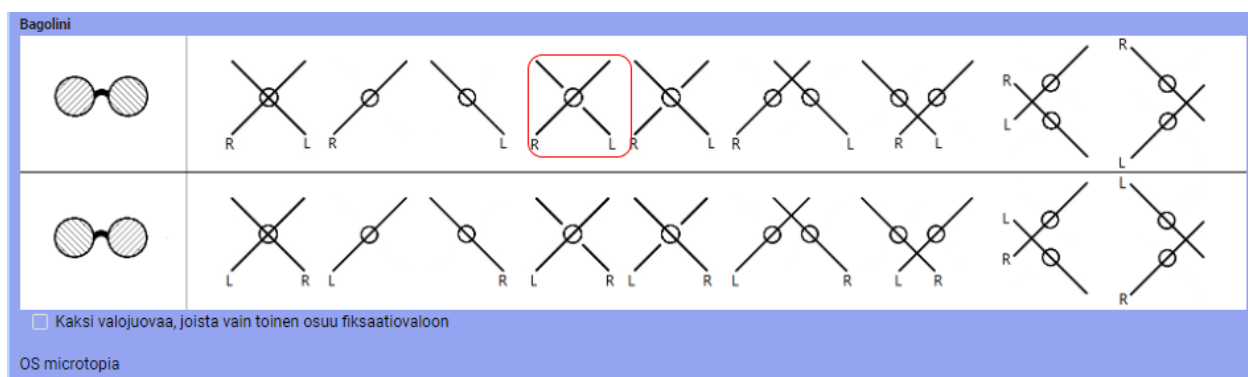
Figure 8: Bagolini striated glasses test: Click the image that the patient sees. The correct deviation (if any) is shown below the test chart (for example OS microtopia).
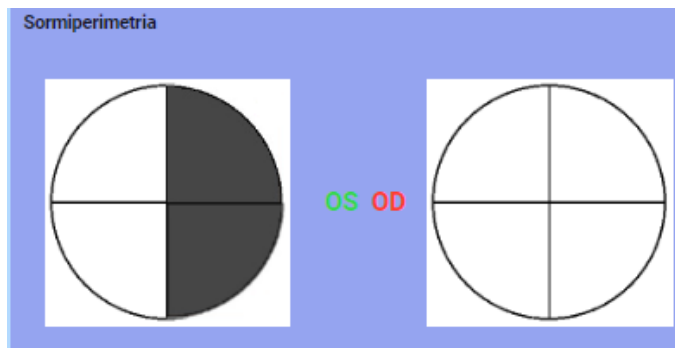
Figure 9: Confrontational visual field test: Click the quadrants that appear deficient. Deficient quadrants are marked dark gray. Note that the visual field here is from the patient's perspective.
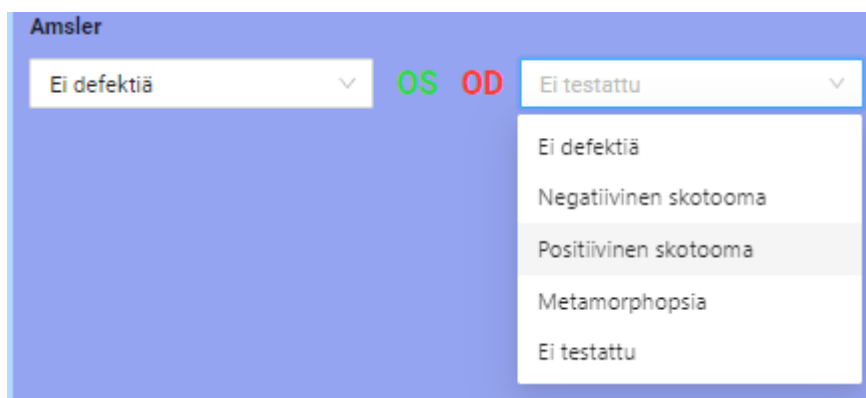
Figure 10: Amsler grid test: Choose the correct (if any) defect. Note that the visual field here is from the patient's perspective.
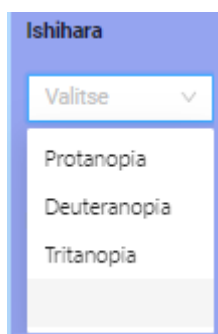
Figure 11: Ishihara test: Choose correct (if any) defect.

Figure 12: Broad H test: Look for any misalignment of the eyes and click the corresponding direction. Choose whether there was any underaction "-", "--" or overaction "+", "++".

Figure 13: The Near Point of Convergence: Mark the correct distance and whether eye(s) diverged.

Figure 14: The angle of strabismus: Mark here the angle of the strabismus (if any). Usually exoforia is marked with "-", and esoforia with "+". Alternatively, you can type in "exo" or "eso" in the free textbox.

Pupillirefleksit

PERRLA: ☐   RAPD: ☐

	OD		OS	
Pyöreä pupilli ☑			☑ Pyöreä pupilli	
Reagoi valoon ☐			☑ Reagoi valoon	
Reagoi toisen silmän valoon ☑			☐ Reagoi toisen silmän valoon	
Reagoi lähelle ☑			☑ Reagoi lähelle	

Pupillin halkaisija valossa (mm) 5.0   3.0 Pupillin halkaisija valossa (mm)
Pupillin halkaisija pimeässä (mm) 5.0   5.0 Pupillin halkaisija pimeässä (mm)
Pupillin halkaisija lähelle (mm) 2.5   2.5 Pupillin halkaisija lähelle (mm)

Figure 15: Pupillary reflexes: If not PERRLA (Pupils Equal, Round and Reacting to Light and Accommodation) or RAPD (Relative Afferent Pupillary Defect), fill in other crucial information when examining pupillary reflexes.

Figure 16: Refraction tab helps you progress through your refraction glasses examination. Blue arrows are used to copy the information to the corresponding fields below. To record visual acuity history (see figure 17) visus-field in refraction-slot must be filled. Dots must be used instead of commas, and only numbers and decimals are allowed (i.e., not 0.4[+1]) if wanting to utilize visual acuity history chart. If there is no valid information in said field, the dots in visual acuity history chart will not be connected. Letters could be useful in cases where the patient only counts fingers or sees hand motion, for example. In these cases the visual acuity history chart cannot be utilized.
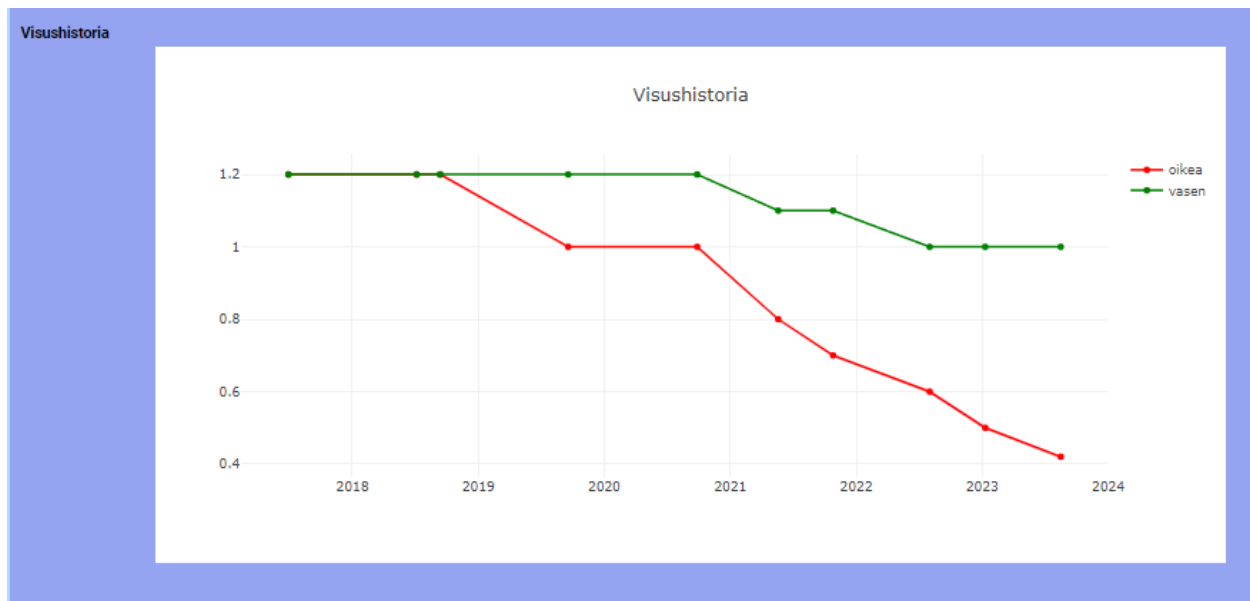
Figure 17: Here is the history of the visual acuity tracked and shown in one easy chart.

Figure 18: Fill here the measured IOP as well as the target IOP and CCT. TR meaning Tonometer Rebound and TA meaning Tonometer Applanation. If both TR and TA sections are filled, TA will be shown in the history of the measured IOP chart (see figure 19). If there is one or more visits in between with no IOP record, the dots in the IOP chart will not be connected.
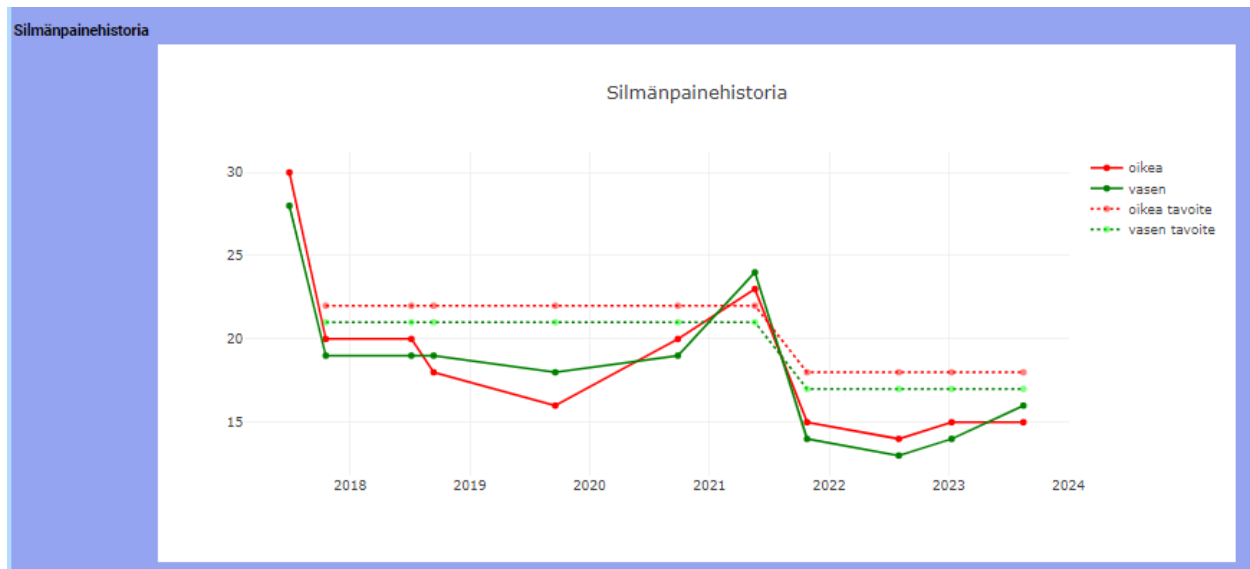
Figure 19: Here is the history of the measured IOP as well as target IOP tracked and shown in one easy chart.

Figure 20: Anterior surface tab helps you progress through contact lens fitting and prescription.
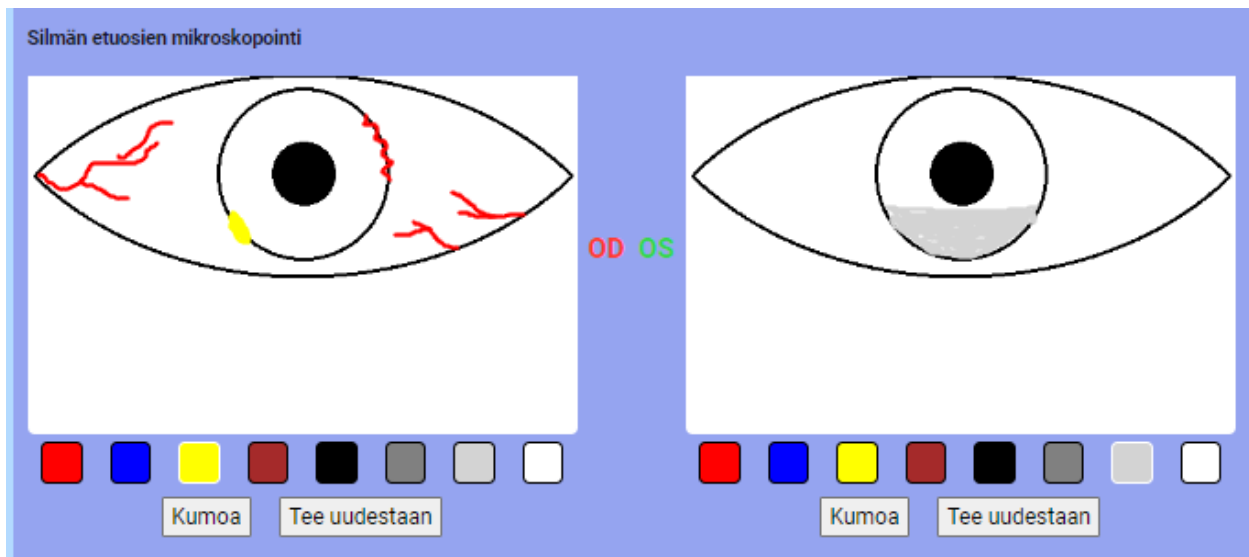
Figure 21: Anterior findings can be drawn here.
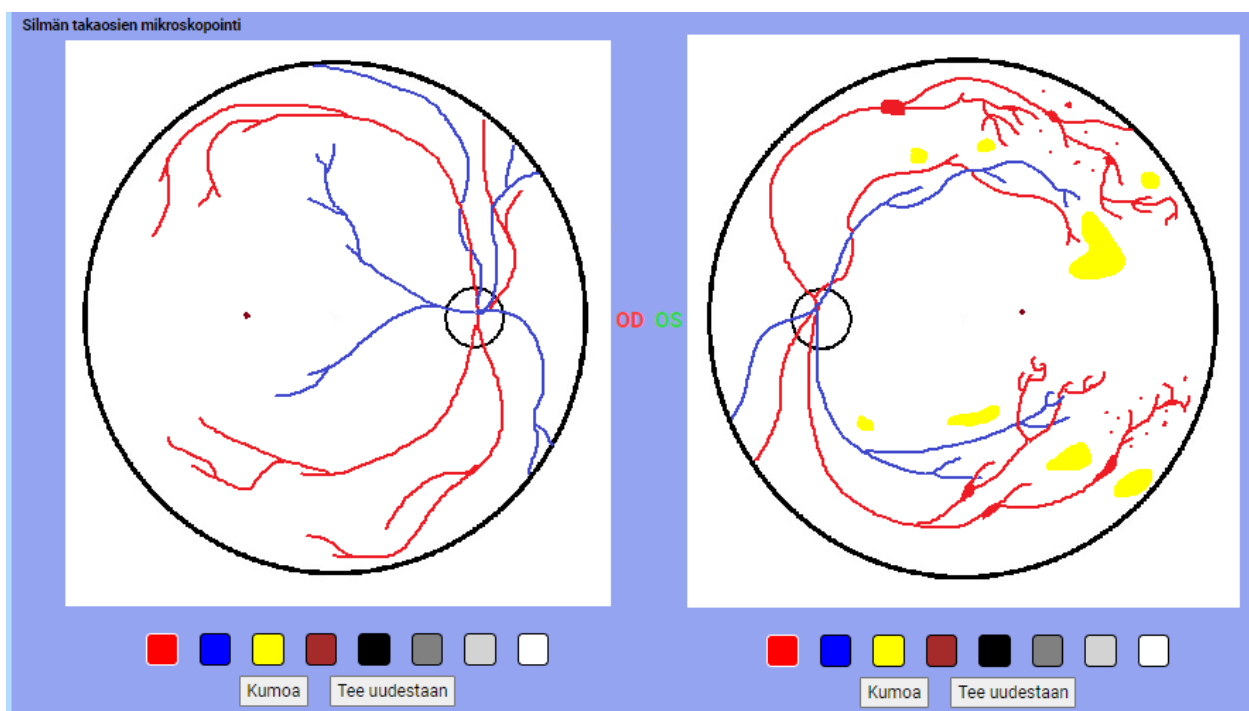
Figure 22: Posterior findings can be drawn here.

Figure 23: Choose whether ISNT-rule applies and mark the cup/disc-ratio.

Figure 24: Up to four diagnoses can be given to the patient.

Figure 25: Write here the treatment plan as well as prescribed medication (if any) and schedule the next examination day.

4.2.3 Discussion

As I have had first-hand experience from a poorly designed EMR, I felt the need to further dive in to the foundations of an EHR/EMR. I felt intrigued to try something totally new. As my idea for a VEMR gained the support of a good friend as well as OUAS's, I felt that the VEMR needed to be done, even if it would only be for training purposes. Later I acknowledged, that limited resources would only suffice for a prototype. Luckily, OUAS still wanted the VEMR to happen.

The idea for the VEMR began in July 2022, when I had to adapt to a new EMR in my working life. I, as well as many of my colleagues, felt that the new EMR was not designed or implemented effectively.

This new working life EMR slowed down the workflow in many ways. For example, by forcing a spherical power to be chosen from a drop-down menu, where the power ranged only from -10.00 to +10.00, starting from the latter (and not from ±0 for example). This would slow down the selection of the power, since all the options had to be scrolled through just to find the correct one. Moreover, I work in an eye hospital, where a spherical power greater than ±10.00 is not uncommon. This immediately creates unwanted workflow impairment, as the real power (if exceeds ±10.00) needs to be written to separate textbox called: "additional information", leaving the "spherical power" box empty since not correct power could be chosen from the drop-down menu. Specialists must be extremely cautious to check every textbox, as not all the information may be where they are designed to be.

Same goes with the cylinder power and the axis of the cylinder. The axis of the cylinder had to be chosen from a drop-down menu. You could only choose axis every 5° and had to scroll through all the options to find the closest axis possible.

Visual acuity had to be chosen from a drop-down menu with options every 0.05 decimal step and up to only 1.00 decimal. For example, visual acuity 0.65 decimal is not very well recognized in Finland, or with the decimal system overall. A preferred marking would be either 0.6^{+2} or 0.7^{-2}, which translate to 0.64 decimal and 0.66 decimal respectively. (Holladay 2004). Visual acuity above 1.00 decimal had to be, again, written down to a separate textbox.

The EMR also had numerous checkboxes, such as if an OCT had been taken or not, but didn't specify whether the OCT had been taken from macula or papilla. This of course needed to be clarified on a separate textbox, leaving the original checkbox for OCT imaging meaningless. The EMR also had many textboxes that seemed out of place, such as current medication being on a tab called: "permanent prerequisites".

Also, when creating a new record for the same patient, the data from the previous visit wouldn't show automatically, and there is no copy-option. After creating a new record, we had to go back to the previous record in order to view what happened last time. This also required manual copy and paste, if some of the patient's information had stayed the same. This happens fairly regularly in a hospital surrounding, for example with injection patients.

With the recourses at hand, not many of the key components for an independent and fully working EMR could be implemented. We had to cut basic features like user authentication and access control, overall security, interoperability, and technical support and maintenance. Thus, leaving ViPo a mere prototype. (See chapter 2.1 "What is an EHR/EMR?" for required features for a fully working EMR).

We also had to cut numerous workflow-enhancing features. Originally there was an attempt to implement a search engine into the prototype, further increasing workflow. With the search engine you could search for certain tests. For example, typing in 'glaucoma', would open up a whole new tab, that has confrontational visual field test as well as the interactive retina pictures and the IOP history chart. We were also planning a help-guide that would guide the clinician through the whole eye examination. The feature would have given hints on how to perform the test at hand, along with some example answers, and what would be beneficial to do next. Some smaller work tools had to be scrapped too, such as auto-conversion of keratometry (dpt) and radius (mm) values, or text suggestions for the diagnoses (ICD-10 recognition).

Since the graphics take up a lot of space and not all information could fit the screen once, some fixed textboxes were attached to the side of the scrollable portion. (See chapter 4.2.2 "Results"). These textboxes are meant for the most crucial information, like patient's current medication, allergies and the reason for the current visit. This is to maximize patient safety and minimize any misinterpretations.

We can see near-to-limitless possibilities with ViPo, when it is done by the right people, for the right people. (See chapter 4.3.2. "Results" for the playtest feedback and improvement ideas).

4.3 Specific Aim 3, Playtesting of the Prototype

The third specific aim for this study was to playtest ViPo in a real eye hospital and optical store surroundings. Playtesting allowed us to gather feedback for further improvements.

4.3.1 Methods

A questionnaire was used to gather feedback for the prototype. (See chapter 8.2. Appendix 2 – The Questionnaire).

4.3.2 Results

As a result, we received a lot of feedback and updated ViPo to version 1.001. The playtesting of the prototype received most of its positive feedback, because it tackled so many of the workflow hindering problems. The playtesting also revealed some minor bugs, as well as bigger improvement ideas.

Here are listed some of the improvement ideas we got as the result of the playtesting:

- An optometrist noted that it would be beneficial to link some checkboxes. Specifically, if RAPD-checkbox was checked, other defect-related checkboxes would automatically be checked for both eyes such as "pupil reacting to light" or "pupil reacting to near stimulus". The right checkboxes could then be unchecked by the clinician. This was our original intention, but the feature had to be scrapped.

- Another optometrist hoped for an interactive visual testing image for Ishihara. This would also be nice, but was left out because we could not create Ishihara visually in a way that would fit ViPo.

- An ability to draw visual defects on an Amsler-chart was also wished for. This would fit the VEMR agenda, however we did not have enough resources to implement a reliable version of this kind of idea.

- One optometrist also hoped for multiple options for contact lenses, as for now only one pair can be chosen per visit. They also mentioned to include a separate text box for used diagnostic medicines (such as Tropicamid). These are good notions and possible to implement in future updates.

- An optometrist also hoped a separate box for CCT (Central Corneal Thickness) for the IOP-tab, as well as NPC (Near Point of Convergence) for motor skills -tab. These updates were included into ViPo retroactively (Version 1.001).

- One test user found the contrast to be somewhat low. Colors were adjusted for more user-friendly experience (Version 1.001). They also wished for more accurate recording for accommodation disorders and strabismus, such as tests for eye movement reserves. This is a good idea and can be implemented to later versions.

- The history of the visual acuity -graph gained praise, but as it was empty for the test users, it caused some confusion. It was suggested to have a clear starting scale, for example showing visual acuity from 0 to 1.0. Now the scale seems odd as long as there are none or only one visit per patient. This can be implemented in later updates.

- An ophthalmologist found drawing with the mouse cumbersome and proposed a tablet drawing possibility. This would of course be a more accurate way to draw, but includes additional hardware, possibly decreasing workflow. Nevertheless, we had no resources to even consider this option for this build.

- Another ophthalmologist proposed to drag different markings (such as □, ∆, ×, ○) into the retina. Each marking would indicate different finding. This would be less cumbersome than hand-drawing.

- One ophthalmologist wanted the tabs to be named after eye diseases, for example: "Glaucoma, Uveitis, Strabismus, Diabetes/AMD (Age-related Macular Degeneration)". This would also be possible. This way however, we would have to include the same tests for multiple different tabs, such as visual acuity.

- Lastly, an ophthalmologist proposed some textboxes for measures, such as machine-observed visual field, panfoto laser, selective laser trabeculectomy and injections for more seamless hospital usability.

One ophthalmologist said that first when the electronic databases arrived, they were criticized for relying purely on text. The ability to draw the findings was removed. He thought that it's good to draw some of the rarer findings when not-so common general phrases could be used.

Another ophthalmologist noted that it may not be a good idea to let the patient see the ongoing recording in the VEMR, as the patient may take fright at some of the drawings or other results seen in the charts. For the patient it may be harder to react when reading the text jargon.

4.3.3   Discussion

The positive feedback mostly constructed from the VEMR's intuitive user interface. Testers felt that having graphically visual tests / test results enhanced workflow drastically, by making both reading and recording of the patient data easier than ever. Both optometrists and ophthalmologists liked that you could freely type in the wanted spherical power, instead of scrolling through a list of powers trying to find the correct one. Especially the history of visual acuity and IOP charts, and interactive Bagolini test gained a lot of praise. Most of the test users did not feel like they needed any additional instructions or introductions to use ViPo.

Many test users grasped the main scheme of ViPo, and proposed many brilliant improvement ideas. Most of these ideas are fully possible to develop in later updates, with better resources and bigger development team.

4.4 Conclusions

We have come a long way from pen and paper. As technology advances, EHRs and EMRs continue to have more and more ways to enhance workflow and the patient data is recorded.

The implementation of EHRs and EMRs has positively impacted the healthcare field in innumerable ways and will keep doing so in the future. The use of these systems has resulted in overall increased efficiency, improved patient outcomes, reduced medical errors, and enhanced patient satisfaction as well as increased the workflow and the job satisfaction of clinicians, and improved the financial performance of healthcare organizations.

One of the most significant benefits of EHRs and EMRs is their ability to improve the efficiency of healthcare operations. These systems have streamlined administrative tasks, such as scheduling appointments and managing patient information, freeing up healthcare providers to focus on delivering high-quality care. Additionally, EHRs and EMRs have improved the accuracy of medical documentation, reducing the time and resources required for manual record keeping.

EHRs and EMRs have also significantly reduced medical errors, which have been a significant concern in the healthcare industry. The use of these systems has enabled healthcare providers to identify and prevent errors such as incorrect medication dosages, drug interactions, and misdiagnosis. Additionally, EHRs and EMRs have improved patient safety by ensuring that healthcare providers have accurate and up-to-date information on a patient's medical history, medication use, and allergies.

Another crucial benefit of EHRs and EMRs is their positive impact on patient outcomes. These systems have made it easier for healthcare providers to access patient information, including past medical history, medication use, and allergies. This increased access to patient data has enabled healthcare providers to make more informed decisions, leading to better diagnosis and treatment options for patients. Additionally,

the use of EHRs and EMRs has facilitated more coordinated care, ensuring that patients receive the appropriate care, even when multiple different healthcare providers are treating them.

Patient satisfaction has also seen a massive uphike by providing a more patient-centered approach to healthcare. Patients can access their medical information easily, including test results, medical history, and care plans. This increased access to information has empowered patients to take a more active role in their healthcare and become more engaged in the decision-making process.

In addition to patient satisfaction, the operating clinicians seem to enjoy their jobs more, when they are using a well-developed EHR/EMR. EHRs and EMRs have enabled healthcare providers to manage patient care more efficiently, resulting in increased productivity and workflow. Workflow enhancing features include easy access, readily available up-to-date information, the easily trackable medication orders, reviewing test results as well as consulting other clinicians with little to no effort. Advanced systems have also automated administrative tasks such as billing, scheduling, and appointment reminders, freeing up healthcare providers' time for direct patient care. These further increase workflow and results in better job satisfactions.

By streamlining administrative tasks and improving efficiency, these systems have reduced operational costs leading to improved financial performance of healthcare organizations. The systems have also facilitated the tracking of patient data, which has helped healthcare organizations identify areas for cost savings and revenue growth. The implementation of EHRs and EMRs has encouraged healthcare providers to participate in value-based care models, which prioritize patient outcomes and reduce healthcare costs. By providing accurate and up-to-date patient data, these systems have helped healthcare providers improve care coordination and reduce unnecessary testing, leading to improved patient outcomes and lower costs.

In conclusion, the implementation of EHRs and EMRs has not only improved patient care and outcomes, but it has also increased the workflow of clinicians and improved the financial performance of healthcare organizations. These systems have streamlined administrative tasks, reduced medical errors, and improved patient safety, leading to better patient outcomes and increased patient satisfaction. Furthermore, EHRs and EMRs have facilitated the shift towards value-based care models, which prioritize patient outcomes and reduce healthcare costs. As healthcare continues to evolve, the use of EHRs and EMRs will remain a critical

component in the delivery of high-quality, patient-centered care while improving the efficiency and profitability of healthcare organizations.

Looking to the future, EHRs and EMRs are likely to continue to play an important role in healthcare systems worldwide. Advancements in technology, such as artificial intelligence and machine learning, may help EHRs and EMRs become more intelligent and personalized, improving clinical decision-making and patient outcomes. In addition, increased emphasis on data interoperability and data sharing may improve the ability of healthcare providers to access and share patient data across different healthcare systems, improving patient outcomes and reducing costs. However, continued investment in user adoption, training, and data security will be necessary to ensure that EHRs and EMRs are used effectively and safely in healthcare systems worldwide.

An interesting direction of development could be integration or transformation from 2D to 3D. What could be more accurate than a description of what is seen, or even a drawn image of what is seen? The answer is: the actual observed object itself.

Virtual reality (VR) and augmented reality (AR) as well as three-dimensional (3D) printing are already being used for example in surgical planning and simulations, intra-operative guidance, patient education, and trainee education. (Wake et al. 2020). Neuro imaging in virtual reality (NIVR) has also been accomplished. NIVR visualization enables physically navigable exploration of MRI scans. NIVR users can experience for example tractography data from inside the brain. The MRI scan data can be scaled to room-size, and the user may walk across the anterior-posterior and left-right axes. (Ard et al. 2017). With the future technology, we will have limitless possibilities when treating and monitoring eye diseases, such as arteritic anterior ischemic optic neuropathy (AAION), for example.

4.5   Reliability of the Research Development Work

This literature review was carried out by only one author. OUAS's thesis supervisors were utilized to ensure the reliability of the thesis. The literature search and the critical evaluation of the studies have been done in cooperation with the supervisors. The cooperation increases the overall reliability, since the supervisors

provided their own perspectives and guidance. Additional feedback for the prototype was conducted from independent individuals via questionnaire.

4.6   Ethicality of the Research Development Work

OUAS guidelines have been used as a basis for this literature review. The work has followed the responsible research (RCR) guidelines for research and procedures for handling allegations of misconduct in Finland. These guidelines were prepared and published in 2012 by the Research Integrity Board (TENK) in cooperation with the Finnish research community. TENK is a board appointed by the Ministry of Education and Culture. (Technical Integrity Board TENK 2021). IRB approval was not needed, as this literature review did not involve any research on human subjects.

4.7   Evaluation of the Research Development Work

Knowing little to nothing on how to create a new EMR and of the consisting framework, I had to do research and self-learning before ViPo could be made. I developed my skills in searching for reliable information online, as well as synthesizing facts into a bigger whole. I also learned how to use a web-page builder and how to organize a playtest setting.

During this process I grew more resilient. I learned that creating an EMR from a scratch is not an easy task, and cannot be made a fully-fletched premium product by a team of two. When you really put your heart into something, every minute detail must be perfected, which is very time consuming. I learned that it is possible for me to work both independently and in cooperation with different instances, even when dealing with a lot of pressure. Thanks to my (and Juha Eskonen's) resilience, all of the issues could be overcome. The process timeline was set to be maximum of one year, to allow me graduate in time. More on timetable and budget in chapter 5 – Timetable and Budget.

5   TIMETABLE AND BUDGET

Conducting of the thesis began shortly after creating the early schematics in July 2022. (See chapter 8.1 "Appendix 1 - The early schematics"). The actual writing of the literature research began in January 2023 and was completed in spring 2023. The productions of ViPo started also soon after creating the early schematics in July 2022. The version 1.000 of ViPo was ready in July 2023 and the playtesting was executed in August 2023. An updated version 1.001 was created as the result of the playtesting. The finalization of writing this thesis could be done after the playtesting and launching of version 1.001.

The original timetable was stretched by factors beyond our control. Originally, Juha and I were supposed to playtest ViPo in summer 2023, and then refine it according to the feedback received. However, December 1st 2022 Plasmic staff released an update which added numerous bugs. After that, during winter and spring 2023 Plasmic received multiple hotfixes. While the hotfixes fixed many issues, new ones appeared in the process. We had to e-mail Plasmic staff to inform the new bugs, so that they could be fixed. Since late spring 2023 we did not face any new bugs, and could continue developing ViPo. This however, cost us valuable time, and we had to first finalize ViPo and then execute the playtest. Only minor improvements and bug fixes could be implemented after the playtesting. We decided not to implement any big improvement ideas, since we were running out of time and resources. Nowadays a well-functioning application or electronic service is updated continuously. Major updates to ViPo would only lead to another cycle of feedback, and again, more updates.

Having a full-time job, family-life and no extra-funding, the prototype had to be barebones. This would mean removed features, such as no backend servers, no privacy security for patient data, only local information storage, and no ongoing maintenance or support. The prototype would definitely not meet the requirements set by the GDPR or HIPAA, and could only be used for training purposes. Building a fully-fletched EMR from a scratch is a complex and challenging process that requires a significant investment of time, resources, and expertise. (See chapter 2.1 "What is an EHR/EMR?" for what a fully working EHR system requires).

Juha Eskonen's total contribution to programming ViPo was approximately 100 hours. My input in programming was approximately 50 hours. We had neither external financial support nor sponsors. Only me and Juha Eskonen.

6   ACKNOWLEDGMENTS

Juha Eskonen – a friend since childhood. Without your expertise in computer science and unyielding mindset this innovation could not have happened. You have my deepest gratitude.

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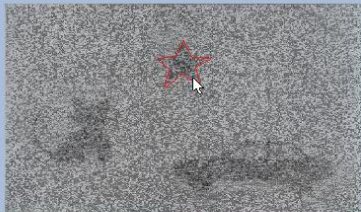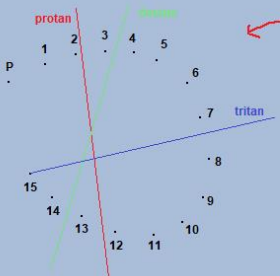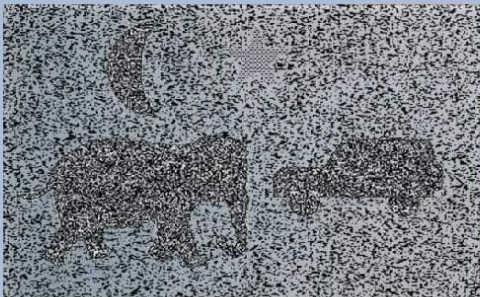
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8 APPENDIX

8.1 Appendix 1 – The Early Schematics

Asiakasnumero 202582

Havainto

Tulosyy

Anamneesi

Stereonäkö

Titmus Fly Test: + / -

Lang I:

Mahdollista klikata kuvia jotka näkee, ilmoittaa stereonäön suoraan kaarisekunneissa, riippuen mitkä kuvat on valittu.

Myös Lang II

Värinäkö

Ishihara:

D15

protan

deutan

tritan

yhdistä pisteet hiirellä, antaa suoraan vastauksen allaolevaan kenttään

P 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Lisätietoja

Diagnoosi

pudotusvalikosta saatavilla kaikki diagnoosit, voi myös hakea kirjoittamalla kenttään

| *Motoriikka* | *Silmälasikorjaus* | *Silmän etuosa* | *takaosa* |

Tulosyy

Anamneesi

H-testi

Liikkeet täydet ja tasaiset

Nystagmus ✓

Jos laittaa täpän niin viereiset kentät sulkeutuvat

vaihtoehtoina -, --, + ja ++

Karsastuskulmat

Johtava silmä

Intermittoiva karsastus ✓

vapaata textiä

Valittavissa kuvat, joiden lisänä teksti, esim:

normaali

tai

uncrossed diplopia

Bagolin linssit

Pupillirefleksit

PERRLA ← *Jos täppä niin testi sulkeutuu*

Pupilli pyöreä ← *Jos ei täppää, niin voi muokata pupillin muotoa hiirellä vetämällä*

Reagoi valoon ✓		Pupilli pyöreä ✓
Reagointinopeus	OD OS	Reagoi valoon ✓
Reagoi toisen silmän valaisemiseen ✓		Reagointinopeus
		Reagoi toisen silmän valaisemiseen

Jos ei täppää, tilalle teksti RAPD

| Halkaisija valossa | | Halkaisija valossa |
| Halkaisija pimeässä | | Halkaisija pimeässä |

Kuvan pupillin koko muuttuu kirjatun millimääräluvun perusteella (min 0,1 mm - max 15,0 mm)

Reagoi lähelle ✓		Reagoi lähelle ✓
Reagoi lääkeaineelle ✓		Reagoi lääkeaineelle ✓
Lääkeaine		Lääkeaine

Pudotusvalikosta valittavissa min -10 mm - max +20 mm

+-0mm yläluomi iiriksen rajalla. -10mm koko sklera näkyy ja +20mm silmä kiinni

Luomet

OD   OS

Lisätietoja

Diagnoosi

pudotusvalikosta saatavilla kaikki diagnoosit, voi myös hakea kirjoittamalla kenttään

motoriikka	Silmälasikorjaus	Silmän etuosa	takaosa

Tulosyy

Anamneesi

Autorefraktio

sf	cyl	ax	prd	bas	visus	OD	OS	sf	cyl	ax	prd	bas	visus
						⬇	⬇						

klikkaamalla kopioi tiedot alempaan kenttään

Silmälasimääritys

sf	cyl	ax	prd	bas	visus	OD	OS	sf	cyl	ax	prd	bas	visus	add

Silmälasien tyyppi ⬇

kaukolasit, lähilasit, monitehot, kaksitehot, syväterävät

Visushistoria

oikea

vasen

IOP samanlainen viivadiagrammi

IOP

Lisätietoja

Diagnoosi

pudotusvalikosta saatavilla kaikki diagnoosit,
voi myös hakea kirjoittamalla kenttään

Asiakasnumero 202582

Tulosyy

Anamneesi

Keratometriarvot

R1	R2	AVG	CYL	DEG	CS	OD	OS	R1	R2	AVG	CYL	DEG	CS	
														mm/dpt

vaihtaa arvot mm ↔ dpt

Piilolinssiresepti

sf	cyl	ax	BC	DIA	visus	OD	OS	sf	cyl	ax	BC	DIA	visus

Piilolinssityyppi ⬇ → Kertakäyttöiset, kuukausi, vuosi, korneaalinen, skleraalinen, hybridi

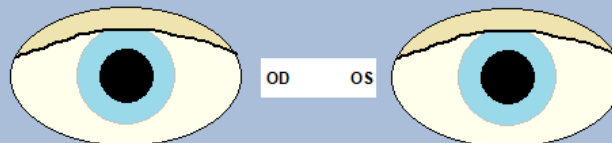**Silmän etuosien mikroskopointi** ℹ ← voit piirtää silmiin verisuonitusta ja muita löydöksiä!

🟥 🟨 🟫 ⬜ ⬛ ⬜ 🩹

Pupilli pyöreä ☐
Punaheijaste ✔

OD   OS

Pupilli pyöreä ✔
Punaheijaste ☐

Pudotusvalikosta valittavissa min -10 mm - max +20 mm

+-0mm yläluomi iiriksen rajalla. -10mm koko sklera näkyy
ja +20mm silmä kiinni

Luomet

| | ⬇ | OD | OS | | ⬇ |

Lisätietoja

Diagnoosi

⬇ pudotusvalikosta saatavilla kaikki diagnoosit,
voi myös hakea kirjoittamalla kenttään
⬇

| Motoriikka | Silmälasikorjaus | Silmän takaosa |

Tulosyy

Anamneesi

Silmän takaosien mikroskopointi   ℹ️ ← voit piirtää silmiin verisuonitusta ja muita löydöksiä!

OD   OS

piirtää C/D-suhteen
suhteen kuvaan

| ISNT | ✓ |
| C/D -suhde | 0.8 |

| ISNT | ✓ |
| C/D -suhde | 0.1 |

Lisätietoja

Diagnoosi

pudotusvalikosta saatavilla kaikki diagnoosit,
voi myös hakea kirjoittamalla kenttään

8.2 Appendix 2 – The Questionnaire

Kyselytutkimus visuaalisesta potilasrekisteristä

Titteli:

☐ optometristi

☐ lääkäri

Mistä pidit visuaalisessa potilasrekisterissä?

_____
_____
_____
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_____

Miten kehittäisit visuaalista potilasrekisteriä?

_____
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