Designing an assistive technology for self-reflection for students suffering from ADHD at Malmö University

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Interaction Design
Two-year Master’s Programme
15 credits
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Abstract (TBD)

Attention-deficit/hyperactivity disorder (ADHD), is a behaviour disorder, usually first diagnosed in childhood, that is characterized by inattention, impulsivity, and hyperactivity. ADHD is often associated with co-morbid disorders like bipolar disorder, anxiety, depression, and substance abuse. The diagnosis of ADHD is clinically established by a review of symptoms and impairment from the child’s young age. There are numerous assistive technologies that exist for people suffering from ADHD but there exists a research gap in developing self-reflective tools for people with neurodevelopmental disorders. This paper bridges this research gap for students at Malmö University. This project will focus on developing a personalized interactive AI-based system that captures contextual data, analyses it to find relevant patterns in user’s behaviour, and visualizes it effectively to provide students with ADHD with insights into the parameters influencing the nature of their disorder. The project is performed under a Double Diamond method which allows for iteration. The methods used mostly comprise co-design methods to ensure the concept caters to the user’s needs. The project is based on learnings from three key areas: Interactive AI, Personal Informatics and Systems as dialogue partners.
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1. INTRODUCTION: AIM AND RESEARCH QUESTION

Attention-deficit/hyperactivity disorder, is a behaviour disorder, usually first diagnosed in childhood, that is characterized by inattention, impulsivity, and hyperactivity. These symptoms usually occur together; however, one may occur without the other(s) (John Hopkins Medicine, n.d.). ADHD is often associated with co-morbid disorders like bipolar disorder, anxiety, depression, and substance abuse. The diagnosis of ADHD is clinically established by a review of symptoms and impairment from the child's young age. All aspects of an individual's life need to be considered in diagnosing and treating ADHD. Psychotherapy alone and in combination with medication is helpful for ADHD and comorbid problems (Antshel et al., 2011). Throughout an individual's lifetime, ADHD can increase the risk of other neurological disorders, educational and occupational failure, accidents, felonies, social disability, and addictions (Sonne, Obel, et al., 2015a).

In this paper, the State of the Art is explored in three categories that were devised by (Sonne, Obel, et al., 2015b):

- **Manually Interacting with Information and Services (MIIS):** These technologies are manually interacting with information and service (MIIS) systems that assist in specific situations.

- **Automatically executing services based on in-situ analysis of context information (AES):** These technologies comprise context-aware technologies that analyse captured data and use this to provide in-situ assistance to the user.

- **Capturing contextual data for later retrieval:** These systems collect data and use this to give insightful information to the users. These insights can be used to self-reflect or for research purposes. This paper points out a research gap in this section.

There exists a research gap in developing self-reflective tools for people with neurodevelopmental disorders (Sonne, Obel, et al., 2015a).

This paper bridges this research gap for students at Malmö University. Therefore, the following research question was formulated:

*How can assistive technology help students suffering from ADHD gain insights into the nature of their disorder to support them in understanding their conditions for personal reflection?*
This project will focus on developing a personalized interactive AI-based system that captures contextual data, analyses it to find relevant patterns in user’s behaviour, and visualizes it effectively to provide students with ADHD with insights into the parameters influencing the nature of their disorder.

The outcome of this project will be to develop and create a prototype of this product and test it with students from Malmö University with ADHD. The final outcome is seen not as a fully functional prototype but rather as a collection of learnings and challenges faced while designing for students with ADHD.

The project is performed under a Double Diamond method which allows for iteration. The methods used mostly comprise co-design methods to ensure the concept caters to the user’s needs. The key stakeholders in this project include Students suffering from ADHD, Disability Services at Malmö University, and Mona Holmqvist – an expert researcher at Pedagogy with a focus on neurodevelopmental children, and medical professionals.

The project is based on learnings from three key areas: Interactive AI, Personal Informatics and Systems as dialogue partners.

The paper begins by describing the design process, the methods used, and the challenges faced while using this method. This project follows an iterative Double Diamond framework that guides co-design methods. It was necessary to follow the principles of Co-design and Relational Design as there was a need for expert opinion. It was important for users to be involved throughout the process as they are the experts on their conditions. The paper then starts to explore the design process. It begins by exploring the real-life problem in its context, focusing on an overview of what ADHD is, research on state of the art, existing research gap in assistive technologies and current interventions provided by Malmö University. It then moves on to explore the results and discussions in the ideation and conceptualization phases. Then, an in-depth explanation of the final concept is presented. The paper then moves on to explain the prototyping and testing stages. Towards the end, the paper also explores how the proposed concept caters to Interaction Design and talks about the ethical considerations of such complex AI-based systems. The final section discusses the future plans for this design concept.

2. DESIGN FRAMEWORK AND METHODS

The following section will explore the design framework, methods used and the challenges faced. This research will follow the principles of Relational design because the following topic demands expert opinion and co-designing at every stage of the design process. During the course Relational Design (Master’s program in Interaction Design) at Malmö University, Relational design was defined as the design that is related to the involvement of all stakeholders so they can have an influence on how the concept is developed and its applications in the future. Inputs were taken from different stakeholders like clinical psychiatrists, disability services at Malmö University and expert researchers. It was important to choose the Relational Design approach for this project as it was important to listen to all the people involved in the design for the design to be fully successful. There was a need to involve co-design
methods in every stage of the design process. These methods had to be modified for each stakeholder depending on their demographic, educational background, expertise, age, state of mind and values. It was important to do this research beforehand to inform the material well (Halse, 2010).

As shown in figure 1, the research was planned with a double-diamond framework, allowing for certain iterations due to time constraints. The double-diamond framework was chosen as it is a linear process but is a modifiable tool that can be used to solve almost any problem. The converging-diverging diamond model was deemed fit to explore the topic to find relevant opportunities and ideate upon it to find the best possible solution.

This section goes deeper into the methods used at every phase of the double-diamond framework and the challenges faced.

![Figure 1: Iterative Double-Diamond Design Framework and Methods](image)

### 2.1 Discover Phase

The main objective of this phase was to identify problem areas within the context of ADHD and to find opportunities that could be worked upon. The research started by getting an insight into the research problem through desk research and interviews/workshops with disability services at Malmö University, psychiatrists and students with ADHD.

The desk research was focused on understanding the nature of ADHD as a disorder to be able to empathise with the stakeholders. Existing interventions, medical treatments, research gaps, and the capabilities of patients suffering from ADHD were researched in detail to understand the context of the problem space. With some basic context in mind, the next stage was to start engaging with the stakeholders.

Interviews were chosen as a research method as it allows for detailed responses from the users and open-ended conversations that help recognize users’ needs. The initial interview was with Dr Sudhir J Reddy, a psychiatrist who deals with patients above 18 years old from the USA. The interview was conducted in a semi-structured way. The interview began by allowing the doctor to explain the nature of ADHD in a real-
life context. Since the interview was conducted digitally via Zoom, it was important to ask a lot of follow-up questions to not leave any room for doubt. The interview was documented in Microsoft Word. The doctor gave some very insightful information regarding how the other stakeholders involved in the patients’ lives are affected by this disorder, the problems that occur in the treatment of such complicated neurodevelopmental disorders, the repercussions of addictive medications, and problems that occur during the diagnosis of patients and the usual symptoms that he has observed in patients. The doctor also recommended some excellent research papers that have been used. After this interview, the problem space opened up a bit more and few opportunities came forward.

The next interviews conducted were with patients suffering from ADHD. Patients were reached out through common friends and online support groups on Reddit and Facebook. The initial interviews were conducted with three students from Malmö University and two people who were approached via online forums for people with ADHD. Confidentiality and ground rules were agreed upon at the first meeting. The structure of these interviews was more open-ended as it was important for the patient to feel comfortable and talk about their personal experiences. The setting was made comfortable for the offline interviews in a secluded space with coffee and cookies. The interview aimed at understanding the patient’s struggles, capabilities and the current usage of assistive technologies. The ones conducted online needed to be a little more structured as the people who agreed to help were only available for a certain time frame. Figjam and note-taking were mainly used to collect information and brainstorm around them.

After the use-situation was determined to be situated with students suffering from ADHD studying at Malmö University, it was important to understand what Malmö University is doing to support students suffering from Neurodevelopmental disorders like ADHD. Eunice Moon who is a mentor at Disability services at Malmö University, and Mona Holmqvist who is a professor at Malmö University whose research is mainly in pedagogy with a focus on neuropsychiatric disabilities were interviewed. The interview with Eunice Moon was done digitally, this interview was structured in nature. A structured interview was chosen as the problem had been framed to a certain extent and it was important to see what the technological interventions provided by Malmö University were. It was important to understand the process and kinds of aids provided to students. However, the interview with Mona Holmqvist was more semi-structured in nature as the aim of this offline interview was to take her help to shape the research problem a little bit more. It was more important for her to guide the conversation and help in opening up opportunities for research better. There was a necessity to go through her research beforehand to ask relevant questions during the interview. Note-taking was used to document important insights during these interviews.

The insights from all the above mentioned research methods has been documented in Section 4.
2.2 Define Phase

After getting insights from the ‘Discover phase’, this phase is where the research question was formulated. Due to time constraints and considering feasibility, students who suffer from ADHD at Malmö University were picked as the design’s target use situation. The user’s main needs, pain points and capabilities were identified in this phase through mappings, empathy maps, personas and goal statements (see Section 4). These methods were used to identify improvement opportunities and empathize with the user. These methods also helped with avoiding any bias and assumptions from the designer’s end. Figma and Figjam were used extensively in this phase to connect the dots and map out the research data.

After gathering insights from interviews and desk research, a research gap was identified in existing technological assistive interventions for students suffering from ADHD. As the design started taking shape, the design was explored in different areas of interaction design. This led to defining the technologies like Artificial Intelligence that could be used to bring the design to life.

Further, an HMW was generated to help inspire ideas in the next phase. After the research gap and use situation was established, there was an iteration back to the Discover phase to interview disability services at Malmö University and expert researcher Mona Holmqvist who is a professor at Malmö University whose research is mainly in pedagogy with a focus on neuropsychiatric disabilities.

2.3 Develop Phase

After the Define phase, there was a basic design framework of the design ready at the convergence point of the two diamonds. The Develop phase was carried out to generate ideas within this framework.

This phase began with conducting a workshop with the primary stakeholder – students from Malmö University suffering from ADHD. Three participants took part in this workshop. The workshop was a self-tracking project that participants had to do in the comfort of their homes. They were given a google form that needed to be filled out and that guided them throughout the process (check Appendix for viewing the document). The main goals of the workshop were:

- Participants had to Track themselves while doing an activity (university-related/ hobby/ work-related).
- They had to track themselves, their environment, and their body while performing this activity.

It was important for the participant to be alone during this workshop so that they could focus on their surroundings and body without feeling judged or watched.

The main reasons for conducting this workshop were:
• Increasing awareness in participants of when or where something is happening so that can be more in control and aware of their mind and body

• Learning about the frequency and intensity of a symptom such as fidgeting, or getting distracted by different factors (digital or environmental)

Based on the insights from this workshop (see section 4), ideation was done with the help of Buxton sketching. Arduino and various sensors like heartbeat sensor, temperature sensor and noise sensor were used to try and visualize how data can be collected from the user’s environment (see section 5).

Low-fidelity paper wireframes and storyboards were created to envision the design and as an attempt to convert the concept to a tangible solution. Low-fidelity paper wireframes were initially sketched on paper and then translated into a digital version on Figma (see section 5). User journey maps were created to identify improvement opportunities in the user’s life. Relevant works were studied to gain inspiration.

The insights from the desk research and workshop led to defining the functional characteristics of the system.

2.4 Deliver Phase

The ideations from the previous phase were scrutinized before heading to the ‘Deliver phase’. Although they were ideations done within a design framework, it was important to revise them before designing the final prototype. This was done by deciding what aspects of the final concept needed to be prototyped given the resources and specific time frame. Houde and Hill devised a model that consists of Role, Implementation and Look and feel to explore the functionalities and the purpose of any given prototype (Houde & Hill, n.d.). Taking this into consideration, the design concept was explored through the lens of this model (see section 7).

Based on this, a preliminary app-based prototype was developed to test on users. The test was designed mainly to observe users’ interaction with the system. This app prototype was designed on Figma. This prototype was tested with three students from Malmö University suffering from ADHD and the system was also discussed with psychiatrist Dr Sudhir Reddy. While testing it with the students, the environment was kept secluded and casual. The users were asked to test the prototype with few guidelines given by the designer. The main aim of this was to see whether the users actually were able to build a relationship with the system and were able to see it as ‘social companion’. This has been discussed in detail in Section 7. A/B testing was used as a method to analyse what type on conversational agents the users engaged with better.

Based on the insights gained from the testing stage, the prototype was iterated. A storyboard was created to depict how the concept would fit into the user’s life at the last stage of their relationship (see section 7).
This phase included working with different materials and technologies to make the solution tangible. The deliverables include a digital prototype and storyboard. After this phase, there exists a ‘Design after Design space’.

2.5 Design after design Phase

There exists a ‘Design after Design space’. This project is going to be a hand-off to future stakeholders to continue upon this project based on the knowledge contributions provided by this project. This phase has been mentioned given the project could not be completed due to the timeline and available process. Hence, the design process is seen as an ongoing process.

3. FRAMING THE PROBLEM

The following section will explore the real-life problem in its context, focusing on an overview of what ADHD is, the state of the art, existing research gap, design guidelines and current interventions provided by Malmö University.

3.1 ADHD

ADHD, or attention-deficit/hyperactivity disorder, is a behavioural condition that makes focusing on everyday routines difficult. It is a commonly occurring brain disorder with significant consequences (McGough, J. J. (2014). ADHD is characterized by inattention, hyperactivity/impulsivity, or both, and thus has three categories: 1. predominantly inattentive; 2. Predominantly hyperactive and 3. combined inattentive hyperactive (Biederman & Faraone, 2005).

Figure 2: Symptoms observed in people with ADHD

According to American Psychiatric Association, the core symptoms of ADHD include careless mistakes, difficulty sustaining attention, inattentiveness, disorganized, unpunctuality and forgetfulness (see Figure 2) (Simon, V., Czobor, P., Bálint, S., Mészáros, A., & Bitter, I. (2009). Comorbidity is very common with ADHD and has to be carefully managed during diagnosis and treatments (Loh et al., 2022). Adults
with ADHD often report instances of long-lasting, highly focused attention on topics of interest. This has been colloquially termed “hyperfocus” (HF). This is often viewed as one of their capabilities. Although this is not currently a component of the diagnostic criteria for ADHD, it is noticed in many real-world scenarios in adults with ADHD (Hupfeld et al., 2019). There is no lab test for the diagnosis of ADHD, but rather a series of reports gathered from family, parents and teachers. Medical evaluations are performed to rule out other possibilities. There has been tremendous progress in the treatment of ADHD over the past few years. Treatments are both pharmacological and non-pharmacological for ADHD. Pharmacological treatments usually include stimulant medications. These medications usually report high efficacy rates. Although, side effects like cardiovascular problems have been reported in a few patients. Non-pharmacological treatment includes parent and teacher training in effective behaviour-management techniques, therapy and behavioural therapy (Antshel et al., 2011).

3.2 State of Art

Most patients with ADHD use traditional tools like organizers, speech-to-text converters, calendars, clocks, lists and reminders to help organize their day. Many patients, parents and partners use online support groups and forums to discuss their problems.

This section will follow the design framework provided by Sonne et. al which introduces three approaches to categorize existing technologies. Each approach correlates to the assistive technology’s functionality. As seen in figure 3, each category of assistive technology is mapped out to various life domains (Social Disability, Academic and Occupational Failure, Health problems/ co-morbidities, Psychological dysfunction, and Risky behaviours) where people with ADHD face problems (Sonne, Grønbæk, et al., 2015).
Figure 3: Existing assistive technologies are explored about challenges faced by patients with ADHD (Sonne, Grønbæk, et al., 2015).

3.2.1 Manually Interacting with Information and Services (MIIS)

These technologies are manually interacting with information and service (MIIS) systems that assist in specific situations. MOBERO, TangiPlan, and ChillFish are a few examples of such systems. MOBERO is a smartphone system (see figure 4) that assists children with ADHD and their families in establishing morning and bedtime routines. This system aims at empowering patients by assisting them to become more independent and thereby reducing stress levels in parents, through a reward-based system. When tested, this system brought about significant improvement in the child’s and parent’s routines. It was associated with an almost 17% reduction in core ADHD symptoms and an 8% improvement in the child’s sleep habits. The design was evaluated by standardized questionnaires (Sonne et al., 2016).

Figure 4: MOBERO – Smartphone app

Time Timer is a commercially available product that aims to aid patients with ADHD assistance with chronic disorganization. It is designed the visualize the passing of time for any given task (see Figure 5). It comes as a wristband, mobile app and various other physical device versions.
3.2.2 Automatically executing services based on in-situ analysis of context information (AES)

Automatically executing services based on in-situ analysis of context information (AES) comprises context-aware technologies that analyse captured data and use this to provide in-situ assistance to the user. For example, ParentGuardian (Pina et al., n.d.) provides in situ parental behavioural therapy cues for parents of children with ADHD, to support parents to better manage stressful situations. It detects the physiological states of the child and provides effective data visualisation to the parents (see figure 5). Based on this child’s state, it recommends suggestions for parents to help reduce their frustrations.

Another example of an AES system for the school context can be found in the smart wristband prototype by McHugh et al. who investigated if analysing anxiety through a heart rate belt could assist children to control outbursts in school. By analysing sensor data from the heart rate belt, the system detects an approaching emotional outburst and notifies the child to use relaxing techniques to avoid it. They found this helped the child stay calm without the help of teachers and parents. CASTT (Child Activity Sensing and Training Tool) is an excellent example of a wearable AES system. It collects movement and physiological data and uses it to assist children with ADHD to maintain attention in school situations (Sonne, Grønbæk, et al., 2015).

3.2.3 Capturing contextual data for later retrieval

This paper points out a research gap in this section. These systems collect data and use this to give insightful information to the users. These insights can be used to self-reflect or for research purposes. Personal Informatics systems are systems that help people collect personal data for self-reflection and gaining self-knowledge (Li et al., 2010). With advancements in technology, collecting data is becoming easier by the day. This poses an opportunity for people with mental disorders to use this to get a better understanding of themselves. There are very few systems that exist to support people with mental disorders.

An example of such a tool is MONARCA (see figure 6), which is a smart-phone based app designed for people suffering from bipolar disorder, clinicians and parents. It collects, analyses, and presents subjective and objective data to provide bipolar patients and clinicians with insights into the parameters influencing the nature of the patient’s disorder. This paper states that developing such a system could be highly beneficial in a disorder like ADHD (Bardram et al., 2012).
Figure 6: MONARCA App interface

Within this opening lies the framing of this project:

Developing an assistive technology that empowers ADHD students by interacting with them regularly and learning. This dialogue partner would help them to understand and track their disorder by setting customizable goals to monitor their co-morbid conditions, improve their organizational skills and maintain their stress levels.

3.3 Background Theory

This section dives deep into the relevant theories like Personal Informatics, Interactive AI, systems as a dialogue partner and Designing for reflective thinking. These theories have been extensively referred to while designing the proposed system.

3.3.1 Personal Informatics

Self-tracking has been revolutionised by the proliferation of sensor-rich smartphones and wearable sensors (Kersten-van Dijk et al., 2017). A community dedicated to self-tracking has been on the rise. Self-tracking has changed how young adults deal with and interact with health-related information (Hardey, 2022). Amid these changes, a new field of 'Personal Informatics' has emerged. Personal Informatics is a subfield of informatics that studies the design and use of self-tracking technologies. The use of such systems differs from person-to-person. A lot of people use it for goal-oriented activities like losing weight, tracking their menstrual cycle or merely keeping track of their health. This field is not only limited to mundane use but has also been rising in the field of healthcare mainly to support patients with self-management and behavioural change (Schimmer, n.d.). As stated in Section 3.2, the MONARCA app-based system for patients suffering from Bipolar Disorder has shown how such Personal Informatic systems can benefit patients suffering from mental health disorders (Bardram et al., 2012). The previous section also states the research gap
that exists in such technologies existing for patients suffering from ADHD. Bardram et. al in their paper on designing mobile-based technologies for patients with Bipolar Disorder state some design needs that need to be taken into consideration to not stress patients who are already under a lot of mental manic. The needs adapted to this design project are as follows:

- Create confidence in the system's usefulness and its integration into daily life
- For the patient to become accustomed to the new technology, they must be introduced slowly and carefully.
- In case of a technical problem, the patient needs immediate assistance.

Rapp. et al. in their paper in their attempt to design a Personal Informatics system for better user experience, state some user requirements to design an efficient PI system after a thorough literature review of existing PI-based systems design (Rapp et al., 2018). The user requirements are as follows:

- Encouraging the integration of different types of data
- Supporting users in remembering their data
- Supporting users in identifying with their data
- Offering different views on data
- Highlighting data correlations

These requirements have been integrated into this project’s design. This has been elaborated upon in the Discussions Section.

The stage-based model by Li. et al has been used to design this Personal Informatics system for students with ADHD. A stage-based model describes the process of using PI systems as five steps: preparation, collection, integration, reflection, and action. In the first stage, users decide how and what kind of data they will allow being tracked. In the collection stage, the data is collected which is then processed from raw data to meaningful data in the integration stage. Reflection on the effective data empowers users through self-insight. The users can use this to take necessary actions which can be suggested by the system (Kersten-van Dijk et al., 2017).

3.3.2 Interactive AI

Information technology has been assisting humans in decision-making by effectively processing data. There exist algorithms that collect data, learn from the data and make data-driven decisions, the brains behind such algorithms is Artificial Intelligence (Anzén & Ekberg, n.d.). This project required the inclusion of AI in decision-making as ADHD as a disorder is a very complex disorder which is very unique to every patient. There was a need for an assistive technology that was able to give every patient personalized insights depending on the data collected. This project focuses more on the human-AI relationship rather than diving into efficient
algorithms and technical specifications. It focuses on building a relationship from scratch between two entities.

Artificial Intelligence can never be viewed as a standalone technology, it always has at least one human being interacting with it. Traditionally, there has been less focus on the social aspect of the human-AI relationship but lately, there has been a massive rise in the interest in the field of HCI (Carolus & Wienrich, 2019). Consequently, AI has begun to become more embodied and interactive. AI has begun to take the shape of a ‘social companion’ rather than a mere tool. Also, since AI has penetrated so many sectors of the industry, it changes people’s views on accepting it (Wienrich & Latoschik, 2021).

Tâm Beran in his paper ‘Can AI and I be friends?’ explores the type of relationship between a given AI and the user. He goes on to explore the aspects an AI should have to facilitate a strong mutual relationship. He explains that for an authentic relationship between them, it is important to consider the personality of the AI. He explores different moral statuses in AI and ponders if life is truly crucial in an AI for this bond to exist. The more ‘human’ the AI seems, the more relatable it becomes to the user. The AI needs to have flaws and unique capabilities that make the human connection to the AI (Beran & Cutas, n.d.).

Like any relationship, the human-AI relationship needs to build over time and over a series of interactions potentially lasting a lifetime. People use lots of strategies and behaviours to maintain and strengthen their relationships with each other. Most of these strategies can be used to strengthen their relationship with computers as well. The basis of any healthy relationship is constant communication, hence routine interactions can be extremely beneficial when it comes to maintaining a human-AI relationship too even though the AI has not been trained to experience strategic human relationship behaviours.

Knapp’s relationship model was used in this design project as an attempt to establish a strong foundation between the human and AI. This relationship model constitutes of two parts mainly: Coming together and coming apart (see figure 7). This project focuses on the ‘Coming together’ part of the relationship model (Welch & Rubin, 2002) . This part consists of five stages:

- Initiating - First impressions are made here, the person usually knows whether they want to take this relationship further or not
- Experimenting - They start getting to know each other and asking questions about each other
- Intensifying - This is usually where feelings heighten and people demonstrate a feeling of ‘trust’ to the other
- Integrating - Here is where there is a fusion and they start becoming a part of each other’s lives
- Bonding - This is usually where they fully integrate into each other’s lives and publicly acknowledge each other as a part of the other’s lives
Keeping this model in mind, this project attempts to take the user from one stage to the next through constant interactions and communication over time.

![Knapp's Relationship Development Model](image)

**Figure 7: Knapp's Relationship Development Model**

This project mainly uses two major functionalities of AI namely: Pattern recognition and Conversational agents.

### 3.3.2.1 Pattern recognition

The science of pattern recognition involves sensing data from the environment, learning to differentiate patterns of interest from their surroundings, and finally making judgments about the patterns or pattern classes (Parasher et al., 2011). A pattern recognition system mainly consists of three functionalities: Perceiving data from the surroundings, extracting the necessary feature from the surroundings and classifying/recognizing featured data amongst trained data (Sharma & Kaur, 2013).

Pattern recognition was important for this project as the concept’s core idea involves Sensing the data from the environment from the user, Analysing and Recognizing the data to make sense of the raw data gathered and finally assisting the user with personalized insightful information. This is explained in detail in Section 6.1. However, this project doesn’t dive deeply into the technical specifications of pattern recognition but rather recognizes it as an important parameter for the design concept to be built in the future.

### 3.3.2.2 Conversational agent

Conversational agents (CAs) are defined as "technologies that take in spoken language as input and provide spoken language as output, engaging in a conversation with the user" (Zheng et al., 2022). Smart CAs such as Alexa and Google home have become an integral part of our lives, but there still exists a research gap for such technologies that have a social impact on minorities, especially patients suffering from Neurodevelopmental disorders (Kumar et al., n.d.).
The main purpose of including a conversational agent in this design was to encourage the user to have constant interactions with the system to help build their relationship. These constant interactions also help the system learn about the user and become more efficient. Hence, the system encourages the user to question its decisions and correct its errors if necessary. It was also designed in a way to help build trust. This is where the concept of Explainable AI (XAI) comes into the picture.

Explainable AI (XAI) is an emerging field of AI which can explain its decisions to the user. Explainability is important in sectors like healthcare, defence and self-driving driving vehicles where trust and transparency are essential (Gohel et al., n.d.). XAI was extremely essential in this project as the user needs to completely trust the decisions made by this system for them to truly feel empowered and comfortable.

The key reasons for including Explainable AI in this project include:

- XAI can enhance transparency and provide information to a layman without making them feel too overwhelmed
- XAI empowers the user by giving them reasons to trust the system. When AI/ML algorithms can justify their predictions and conclusions logically and scientifically, humans are more likely to favour their conclusions or predictions

**3.3.3 System as a Dialogue Partner**

These kinds of human-machine relationships are seen as a cyclic interaction between the machine and the user (Hornbæk & Oulasvirta, 2017). Norman’s seven-stage model states that these kinds of dialogue are comprised of stages. There are two main categories in this cyclic communication: Gulf of execution and Gulf of evaluation which maps to the user’s intention with the system and the user’s interpretation of the system (see figure 8) (Norman & Draper, 1986). In the former, the user beings with a goal of what the user wants from the said machine, formulating a plan to execute this goal and executing this goal with the system. During the Gulf of execution, it is important for the user to move easily from their needs to express these needs to the system. Mappings become an important factor to consider here, where the user can express their intentions to the system and be aware of how to control the system to get the appropriate results from it. It is important for the UI to guide the users through this journey in a way that they don’t get too overwhelmed, especially when the user has a Neurodevelopmental disorder. This is discussed further in Section 6.2.

The Gulf of evaluation is all about how the machine provides feedback to the user and how easily the users can interpret this feedback given by the system.
Unlike any other assistive technology, the design concept presented in this paper needs to behave as a 'social companion' rather than a tool that the users can use in particular situations. This is because the system proves to be more useful to the user as their relationship matures over time, the concept demands constant interactions between the human and the machine so that the machine can learn about the user and be more efficient. Hence, it is important to devise a simple, clear and direct UI (Hornbæk & Oulasvirta, 2017).

### 3.3.4 Designing for reflective thinking

In the field of HCI, reflection refers to the act of thinking about the information provided by computational systems to become more self-aware about actions and consequences (Ghajargar et al., 2018). Reflection is not a user’s problem that needs to be fixed but rather is an ongoing continuous task that needs to be continuously endorsed. It was a challenge to design for such a continuous ongoing activity compared to other assistive tools that usually are problem-solution oriented.

Ghajargar, M. et al. in their paper explore different types of objects for reflection, which they divide into two categories: Eco-feedback designs and critical design objects (Ghajargar & Bardzell, 2021). Eco-feedback designs are usually everyday use objects that usually call the user’s attention to resource-based awareness. Critical design objects are designed to bring awareness to certain debates and political discussions. The concept proposed in this paper belongs to neither of these categories but is rather a design that attempts the user to reflect on themselves, more specifically the conditions of their disorder. Although, one characteristic common to the proposed concept and the above-mentioned reflective designs is the ‘attention grabbing’ of the users. This system uses notifications and sounds to remind the user to interact with the system every day to become more efficient.

Ghajargar, M. et al. in their paper talk about different types of relationships that exist between humans and computational tools. They also devise a new kind of relationship for tools for reflection called the ‘make me think’ relationship (Ghajargar
et al., 2018). This relationship has a few key characteristics that are relevant to the design proposed in this paper:

- The system and the user exist in a balanced relationship
- The user always has control over the relationship
- The system exists not to assist the user in any single task, but to make the user think and reflect
- The user has to undertake a certain action concerning the system which should be related to another activity that needs reflection, for example in this concept - tracking the user’s co-morbid conditions.

The proposed design concept adopts these characteristics from the ‘make me think’ model.

Ploderer et al. present a review of existing systems that use social interactions and reflection as a mode for behaviour change in their paper (Ploderer et al., n.d.). One of the described systems – The Reflection On Action system is the category under which the proposed system falls under. This kind of system offers reflection after a certain activity has been completed rather than providing in-situ assistance. The proposed concept also encourages the user to interact with the system at the end of the day rather than during school-related activities. The key challenges in designing such systems include a choice of data collection, data correlation and extent of ambiguity provided during insights (Ploderer et al., n.d.).

3.4 Design Guidelines

This section dives into the Design guidelines adopted in this project by Sonne, et al. In this paper, the authors provide a framework on how to design assistive technologies for students with ADHD (Sonne, Obel, et al., 2015c). The framework consists of three categories: sensing, recognizing and assisting (see figure 9).

Sensing involves the collection of physiological states of the patient through a wearable, recognizing involves making sense of the data collected and assisting involves helping the patient in any situation. It provides important guidelines for each of these sections.

![Figure 9: Design framework provided by Sonne, et al.](image-url)
Due to time restraints, the research project focuses on the ‘assisting phase’ for ADHD students. The following guidelines have been used to make design decisions during the course of the research project:

- To capture and hold a child’s attention, the intervention style must be engaging and intuitive.
- Including clear rewards in an assistive system can have an impact on the child’s behaviour and heighten their interest in the system.
- The intervening aid must alert the student in a covert manner that doesn’t disturb the other students.
- Children with ADHD frequently struggle with timing and handling changes in activities. As a result, assistive interventions should offer a natural conclusion and precise instructions for what the child should do immediately after.
- Children with ADHD frequently misplace their stuff. Consequently, an assistive intervention should use the child’s own computer or smartphone.

### 3.5 Interventions provided by Malmö University

To understand the services provided by the university, a detailed study was done on the website and mentors from Disability Services were interviewed.

To use the Disability Service provided by Malmö University, a student has to undergo a lengthy procedure. This process includes - obtaining a diagnosis certificate from a certified medical professional from Sweden, uploading the diagnosis certificate to the university system, writing an article and filling in questions about the program to which they are admitted. This is then analysed by the university and appropriate services are provided to the student.

A few interventions provided by them include the following: Notetakers so the student doesn’t feel overwhelmed, extra supervision hours, special rooms and extra time during examinations, and providing lecture material in advance to help the student prepare. Disability Service at Malmö University consists of mentors, coordinators, guides, student volunteers and faculty members. Volunteers and mentors have to undergo special training before interacting with students. The technological interventions provided by Malmö University are limited, they include Dictaphones, digital highlighters and smart pens.

The ADHD student's interviewed used almost none of the services provided by the university.

### 4. UNDERSTANDING THE PRACTICE

This section will explore the insights gained in the Discover and Define Phase of the design process.
4.1 Fieldwork and Desk Research

The first step was to understand the needs, concerns, capabilities and wishes of people with ADHD and the other actors involved in their lives. This was done mostly based on literature studies, interviews and analysis of online support platforms. The key problems and flow of information are summarized in figure 8. Interviews were conducted with different actors such as five adults suffering from ADHD (three studying at Malmö University), clinical psychiatrist Dr Sudhir Reddy who specializes in the diagnosis of Neurodevelopmental disorders in adults, and Eunice Moon who is a mentor at Disability services at Malmö University, and Mona Holmqvist who is a professor at Malmö University whose research is mainly in pedagogy with a focus on neuropsychiatric disabilities.

Based on desk research few common challenges faced by patients with ADHD were identified:

- The high degree of inattention often described as ‘daydreamers’
- Stigmatization from friends
- Poor organizational skills
- Procrastination
- Prone to losing and misplacing things
- Prone to behave recklessly which often leads to substance abuse and accidents
- Restlessness, often interrupting others and being poor listeners, hyperactivity
- Poor social skills
- Often face additional challenges due to co-morbid conditions
- Emotional dysregulation

After the initial desk research, an interview with a clinical psychiatrist was conducted to understand the nature of the disorder, the diagnosis process, and treatment. Some of the interesting insights from this interview include:

- The cause of ADHD is still not established, it is never a single cause but rather a combination.
- Diagnosis is done through Checklists mostly - depends on physicians
- Conners rating scale is used during diagnosis
- Treatment includes psychotherapy, medications and behavioural therapy
- Doctors often tell them to maintain schedules and reminders, tell them how to prioritize
- Doctors recommend self-help books to encourage them to become less dependent
- Partners and parents of patients often undergo therapy too as they often feel stressed due to the patient’s condition
- A few challenges include overdiagnosis of ADHD, side effects of medications, abusing of medications and monitoring each patient’s progress.
- Diagnosis and treatment take time, and most of the time each patient is not able to receive enough attention due to a lack of resources.
Based on the knowledge obtained from desk research and interview with the psychiatrist, a workshop was created to interview students suffering from ADHD. The key goals of the interview were to identify real-world scenario problems of students. Students from different cultures and age groups were interviewed to ensure the final concept was inclusive. These are a few interesting insights gathered from students:

- Everyday mundane things get boring
- At younger ages, it was difficult for them to start tasks and hyper-fixate on started tasks
- Most of them felt stigmatised as young kids - writing tests in different rooms, reduction and flexibility of homework caused them to feel left out
- Nobody educated students about neurodevelopmental-disabilities
- Difficult to tell what symptoms come from ADHD or comorbid conditions
- Procrastinating was a common symptom
- Fear of substance abuse problems
- Most of them faced problems with social skills
- All of them said they were very forgetful and had poor organization skills
- All of them reported to be creative and possessed very unique hobbies and interests
- Most of them suffered from ADHD affecting their relationships
- They faced issues like stress and anxiety due to the above-mentioned symptoms
- Assistive technologies used include Google calendars, digital lists, Notion, physical calendars and planners

Due to time restrictions and feasibility, the research project’s use situation was established as students suffering from ADHD at Malmö University. Apart from desk research, Eunice Moon, a special educator working with disability services at the university was interviewed to get to know the point of view of other stakeholders involved. Key insights gathered from the interviews and research include:

- There are no technological interventions provided by the university
- The students suffering from ADHD don’t make use of any of the services provided by the university except for examination resources (extra time, hour logs, separate rooms).
- The mentors in the disability services access the student’s CANVAS to track their progress
- Mentors undergo training from government institutions to be eligible
- Most students are unable to keep up with their course
- Courses are advised to be designed keeping in mind students with ADHD, but this rarely happens

Mona Holmqvist was interviewed to get a better understanding of the pedagogical practices at Malmö University concerning students with neurodevelopmental disorders. Few insights gathered include:

- Most students often struggle with self-organization
- They also struggle with navigation within the campus
• They are best suited to do singular things, but the courses are rarely structured like that

4.2 Synthesis of Data

To gather the information from the Discover phase to make sense of it, mappings, empathy maps, personas and goal statements were created. Initially, a mapping to understand the relationship between the patients and the different actors involved in different life domains was made (see figure 10). This mapping consists of the actors, the environment, observable patterns in the patients and the repercussions of their actions on the other actors.

![Figure 10: Observable patterns and actors involved in the life of a person with ADHD](image)

Based on this and the insights from the previous phase, an empathy map and persona were created to help empathize with the users. The empathy map consists of four sections: says, thinks, does, and feel. This was done to understand interpretations of the user’s words and behaviour during the interview (see figure 11).

To empathize with the user further, a persona was created to get deeper into the target user group and capture their personality. Personas allowed us to see the users as humans with needs, capabilities and flaws (see figure 12).
Figure 11: Empathy map

**SAYS**
- easy for me to get addicted to alcohol; I saw my dad drinking and getting into substances; I try really hard to keep myself in line
- Difficult to tell what symptoms come from ADHD or Asperger’s
- Can’t handle distractions while studying - I use noise-cancelling headphones/lyric-less music, study alone
- The lack of attention sets my work pace on which leads to extreme anxiety
- I always come/read myself that I was just lazy but where I come from there isn’t much information about ADHD, so my parents didn’t really think to get me tested
- I think I’m super-creative
- Google Calendars - I enjoy it a lot
- SDD document - a lot of meetings between parents, psychologists, teachers and principals to provide this
- Meds helped a lot (trials) - not many side effects
- Parents struggled to help me get my work done
- I’ve lived with multiple partners; they get frustrated
- My apartment is almost always dirty, it’s difficult for me to clean my apartment

**DOES**
- Student who studies at Malmö University
- Almost always procrastinates her assignments and studying for exams
- Still remembers to get good grades
- Parties with friends by drinking a couple of beers on the weekend
- Has a partner who she’s been together with for 8 months

**Figure 12: User persona**

**Bio**
Eva is a student at Malmö University who was diagnosed with ADHD when she was 8 years old after her teachers suggested to her parents. She has the combined type of ADHD. She also suffers from Aspergers. She often has problems concentrating on her assignments and studying for her exams.

**Demographic data**
- 25 years
- Female
- Single
- Studies at Malmö University

**Assistive tech used**
- Google Calendars
- Digital Lists
- Canvas

**Goals**
- To graduate with good grades
- Have a healthy relationship with partner
- To travel and make the most of life
- To keep mental health in check

**Frustrations**
- Unable to focus
- Easily distracted
- Doesn’t understand the nature of her disorder
- Unable to do mundane activities
- Sad about how it affects her loved ones

“Can’t handle distractions while studying - I use noise-cancelling headphones/lyric-less music, study alone”

“Difficult to tell what symptoms come from ADHD or Asperger’s”

“I think I’m super-creative”

“My apartment is almost always dirty, it’s difficult for me to clean my apartment”
Based on these insights gathered, an HMW was drafted to enable idea generations for the next phase:

HMW design a tool that captures, analyses and visualizes contextual data to provide students with ADHD with insights into the parameters influencing the nature of their disorder to support them in understanding their conditions.

5. IDEATION AND CONCEPTUALIZATION

The following section will explore the Develop phase of the design which included mappings, relevant work-study, ideation workshops, crafting user stories, storyboarding and designing low-fidelity wireframes. The ideation and conceptualization went hand in hand.

At this stage of the design process, there was already a general idea of how the system will function. As described in 3.3, Sonne, et al. have come up with a design framework as to how to design assistive technologies for people suffering from ADHD. With the guidelines adapted from this framework, a rough concept was drafted.

An ideation workshop was conducted with three students with ADHD from Malmö University. This ideation workshop was focused on understanding what kind of data should be captured from the user environment and body states and the type of insights the design should provide to empower the user. The design probe sent to the users consisted of:

- Instructions on what kind of activity to track
- Help on how to self-report
- The questions came with prompts to guide their thinking process

All the users reported that they enjoyed doing this activity as it helped them look inward and retrospect their actions. A self-report was used for the workshop instead of direct observation as it was important they were their truest self during the activity without feeling awkward and judged. Key insights from the workshop:

- The student’s environment contributed to them getting distracted
- Apps and notifications distracted them often
- Restless leg shaking, nail-biting, fidgeting and other impulsive body movements occurred when they felt stressed or overwhelmed
- They had the intent to finish the task on time but never could
- They felt distracted by thoughts in their head

With these insights and following the guidelines given by Sonne, Obel, et al., a preliminary concept was established. User stories were crafted to observe the envision the user in different scenarios and find improvement opportunities to empower them.
Desk research was conducted to understand the type of relationship between the system and the human. To try and dig deeper into the concept, Buxton sketching was used to try and envision the system through different mediums.

Arduino and sensors were used to explore different materials such as sensors like accelerometers, heartbeat sensors, noise sensors and temperature sensors (see figure 13).

![Figure 13: Buxton sketching with Arduino and heartbeat sensor, temperature sensor, accelerometer and noise sensor](image)

During this phase, based on all the insights from workshops, ideations and desk research, there was a necessity for a personalized system for each user for them to get the most out of it. The framework provided by Sonne, Obel, et al., was revised to fit the design’s requirements. (see figure 14)

![Figure 14: A revised design framework for designing assistive technology for ADHD](image)

There was a need for the system to be able to recognize patterns and make sense of the data before effective visualization. This way the user could get personalized insights into their conditions. Keeping this in mind, the relationship design between the user and system was explored further.

Low-fidelity paper wireframes were created to start imagining the relationship between the system and the human. This also helped identify a few UI design guidelines that had to be followed to help a person with ADHD navigate through it without feeling overwhelmed (see figure 15).
6. MAIN RESULTS AND FINAL DESIGN

6.1 The Concept

As explained in the previous section, the different positive characteristics of the concept ideation were integrated to create Alex - A dialogue partner for students with ADHD. This system is a ‘Reflection On Action’ system as described in Section 3.2.4 meaning this system does not provide in-situ assistance to the user but rather provides the user with an opportunity to reflect after the task has been completed.

The intent of the design consists of its purpose, value and trust. Some important design considerations after gathering the needs, values and capabilities of the user in different phases include:

- The main purpose of the system is to provide users assistance in coping with ADHD in university-related issues, to provide insights into their mental health, and empower them by helping them self-reflect on the nature of their condition.

- The value it brings is personalized assistance for the user to help the user reflect on themselves and help them become independent and efficient.

- Trust between the human and the system is extremely important for the concept to function effectively.
As seen in figure 12, the system is divided into four phases: Sensing, Recognizing, Analysing and Assisting. This project focuses on the system’s expression and the ‘Assisting’ phase (as highlighted in figure 16). The system comes with a pre-trained dataset of the most common traits of ADHD and how it is expressed in the user’s world.

Figure 16: System flow chart

As mentioned above, Sonne, Obel, et al., have described a design framework that explicitly guides users on how to go about each category: Sensing, Recognizing and Assisting. In the Sensing phase, a few key insights this concept has adapted from Sonne, Obel, et al., include:

- The device should not come in the way of the student’s everyday activities
- The design of the device should be sturdy and tough to withstand university activities
- To provide insightful information to the users, the data must be continuously collected in real-time.
- The design of the device should not attract too much attention and should not make the student feel stigmatized
- The device should be easy to set up

In the Recognizing phase, a few key insights this concept has adapted from Sonne, Obel, et al., include:

- Gathering data from seated positions only: Based on the ideation workshop and observing students at the university, it was noticed that most often students are working sitting down. This insight helps to gather when the student is feeling restless, which is detected by a lot of movements while sitting down.
- Detecting transitions in physiological states, like a sudden spike in body temperature or heartbeats usually indicates stress.
- Walk detection is adopted by the situation to make sure data is not unnecessarily collected from the user. Walking is considered an ‘off’ switch for the system.

Since there has been extensive research on designing systems that sense and recognize data for students with ADHD and due to time constraints, this research project focuses on designing the interactive experience between the user and the system in the ‘Assisting phase’.
As mentioned in Section 3.3, the design guidelines are adapted into the system’s design.

Alex is a system that consists of a physical device that consists of sensors to collect data from the world and the user. The device collects the following data:

- **Physiological data**: heartbeat, body temperature and body movements through heartbeat sensors, temperature sensors and accelerometers
- **Calendar & Canvas**: To track the schedule of the student
- **App Notifications**: To understand the social activity and its influence on students
- **Screen tracking**: To understand key distractions in the digital space
- **Environmental data**: Noise from surroundings, location tracking, the outside temperature

These collected data are sent to the Machine. The machine with the help of Pattern Recognition algorithms senses the data, identifies the required data from its environment and attempts to match it with different data to find relevant patterns and insights. The machine then uses its application of logic to make the most appropriate decision. This decision is made based on the Knowledge the system possessed. This knowledge is a collection of information the system has learnt from the user’s behaviour and the pre-existing knowledge which it was trained with.

For example, if the system noticed an upcoming exam in the student’s schedule and if it detects increased stress levels (combination of the heartbeat sensor data, body temperature sensor data and accelerometer data), using Pattern Recognition, the system makes an attempt to find patterns in this random data. It can connect the dots to come to the conclusion that the student is stressed out due to an upcoming exam. It then provides them with insights concerning their stress, organizational skills and how to cope with stress. The user can then self-reflect on these insights and make an informed decision on what action to take. If they do not agree with the system’s insights, they can also go and question why the system came to such a conclusion. This interaction can help the user and the system learn more about the user’s condition.

These insights and decisions are then expressed by the machine to enable the user to digest information easily. The data visualization of insights was complicated to design for students with ADHD. After doing some desk research and listening to lectures about accessibility from Gareth Ford Williams and Dan Norman, a few guidelines were gathered before designing the interface, these guidelines include (Mcknight, n.d.):

- Using ‘calm’ and cool colours to provide a calming effect on the users.
- No unnecessary graphics and decorative elements that might distract the user from the necessary task at hand
- Distinguish important information by putting it in bold or colour to guide their reading
• Grouping related information into segregated sections to aid the student
• Use large fonts and a clear sans-serif font to enhance readability
• Minimise surprises, always tell the user what to expect next
• Exclude unnecessary animations in the design.
• Avoid showing heaps of information at a time as people with ADHD find it difficult to grasp multiple types of information at once, they possess a very singular way of digesting information.

Another important aspect of the concept is the conversational AI which occurs in the assisting phase, here is where the AI explains its intent and reasoning behind its decision-making with complete transparency in a way that the user can comprehend. The conversational AI is also a medium for the user to correct the errors and assumptions made by the system.

For example, as shown in Figure 17, the system makes a suggestion for the user to organize their day better. It suggests that the user could read a paper due for one of their lectures in the morning. If the user wants to know why the system made the following decision, the user can simply click on the icon marked with a question mark, which allows them to open up a dialogue with the system. The system then takes the user through every decision made step by step to not overwhelm the user with jargon they cannot understand. If at any stage, the user is not satisfied with the system’s thought process they can immediately inform the system. This way, the system learns more about the user’s behaviour to be more efficient and the user gains more trust in the system.

Figure 17: Conversational AI agent
6.2 The Human-System Relationship

Hornbæk et al. in the paper ‘What is Interaction’, explore the different types of interactivity between a human and a system (Hornbæk & Oulasvirta, 2017). This concept envisions the system and humans to be dialogue partners, where they both are continuously learning from each other existing in a symbiotic relationship (See figure 13). As described in section 3.3.3, the concept aims to build the Gulf of execution by having an easy-to-understand onboarding process which helps the user understand the capabilities and flaws of the system. It then enables them to self-report their diagnosis and helps them set goals using easy-to-use UI mappings. It attempts to help the user translate their cognitive goals into inputs that can be easily understood by the system. Once they start using the system, the system also enables a smooth Gulf of execution phase, where the system provides easy-to-understand feedback to the user. The user can interact with this feedback via a Conversational agent, this interaction helps the symbiotic relationship between the Human and the machine mature over time. This relationship helps the system and the user understand each other over time effectively.

Figure 18: Observable patterns and actors involved in the life of a person with ADHD

The concept in this paper aims to build a strong relationship between the AI and the user over time. It focuses on developing a friendly and non-judgemental AI to make the user feel more comfortable.

Artificial intelligence was chosen for this concept to analyse the data as it has the capabilities to simulate human intelligence. One of the most common use cases for AI includes pattern recognition. Hence, it seemed the best fit for this concept.

In this concept, due to the scope of the project, it is speculated that such a human-like AI can be developed. As mentioned in this paper, speculations need to be grounded in reality. Given the current advances in ubiquitous computing and AI agents, many companies like IBM, Google and Microsoft are progressing towards creating such an AI system. Hence, it is not uncanny to imagine such an agent exists (Auger, 2013).

As explained in section 3.3.2, the main functionalities of the proposed AI system are pattern recognition and conversational agent. This concept focuses on the interaction
part of the human-machine relationship rather than developing the most advanced AI. This is called Interactive AI (refer to section 3.3.2), which is discussed further in the Discussions Section.

As stated in section 3.3, to design this relationship, Knapp’s Relationship model has been used to envision the relationship and build it one layer at a time (Avtgis et al., n.d.). This relationship development model has been used by IBM in designing their AI agents. Since this concept focuses on developing a steady relationship between the user and the machine, it focuses on the ‘Coming Together’ part (see Figure 7).

As described in section 3.3.1, this project uses the stage-based model by Li. et al to design this Personal Informatics system for students with ADHD (see figure 19). A stage-based model describes the process of using PI systems as five steps: preparation, collection, integration, reflection, and action. In the first stage, users decide how and what kind of data they will allow being tracked. They give permissions to the system (for example: linking their CANVAS, allowing their location, and giving access to sensors and calendars). In the collection stage, the data is collected which is then processed from raw data to meaningful data in the integration stage through principles of Pattern Recognition and Machine Learning. The users are then presented with relevant insights through effective data visualization. Reflection on these insights empowers users through self-insight. The users can use this to take necessary actions which can be suggested by the system. These actions can include correcting the system of its errors via the conversational agent or using it to tackle their disorder. This action in return is fed back to the system for it to learn about the user’s behaviour over time.

![Figure 19: Stage model of Personal Informatics systems](image)

As seen in Fig 7, every relationship requires maintenance. As seen, this happens in phases: Initiating, Experimenting, Intensifying, Integrating and Bonding. Due to time restrictions, the prototyping and testing were conducted only for the Initiating and Experimenting phase. In the initial phase, Knapp states that snap judgements and first impressions are usually made, where the user will decide if he/she wants to continue using the system. Hence, it is important to establish a tone and personality the human can relate to. This concept aims at establishing a friendly and trusting tone to help nudge the user to the next stage (see Figures 20 & 21).
Figure 20: Initialising phase was done via app screens to understand how users interact with the concept

The experimenting phase (figure 22) is where both parties start experimenting and getting to know each other. This stage is where the user starts exploring the possibilities of the system and establishing what they want to get out of it.

The concept aims to give insights into the following fields:

- Stress levels
- Distractions in various locations
- Sleep cycle tracking and its effects
- Self-organization
• Comorbid condition monitoring

The next stages of the relationship model include Intensifying where reciprocal sharing is key to ‘intensifying’ the new relationship. Here, designing levels of context-aware interactions is key. Next, in the Integrating stage, it is expected for the AI to run smoothly while building a sustainable relationship. Here, it is expected for the AI to have a profile that can be observed by the user. In the last stage, Bonding, the user and AI are seamlessly integrated into each other’s lives. That does not mean it stops there, like any other relationship, this relationship needs to be constantly worked on to be efficient and keep the user happy. This stage is depicted using a storyboard to envision how the final design concept will be integrated into the user’s life (see figure 26).

Although the system has a lot of information it could give the user, it was essential to allow them to set goals and expectations to manage their self-reflection. It was also essential to establish trust, by guiding the user through the system’s decisions so they are always aware of how their data is being used. Based on the conceptualization, a user flow was created to envision the user’s journey through the system before heading to the prototyping phase (see Figure 23).

Figure 22: Experimenting phase, focused on encouraging the user to explore the system and get excited by it. It also aimed at creating a bond with the user through trust.
Houde and Hill described Prototypes as “a representation of any design idea regardless of the medium” (Houde & Hill, n.d.). They devised a model that consists of Role, Implementation and Look and feel to explore the functionalities and the purpose of any given prototype. Taking this into consideration, this section explored the prototyping done for this concept through the lens of this model. These choices were made to give the audience a grasp of the concept rather than building a full-fledged working prototype.

7.1 Implementation

Based on the insights gathered in the previous phases, the ‘Sensing’ phase of the concept was explored via an Arduino Nano. Heartbeat pulse sensors, accelerometers, temperature sensors and noise sensors were used to ideate the concept (see figure 13). As shown in the figure, this is an initial rendering of the prototype. As discussed in the Discussions section, the future work of this concept consists of material exploration for the wearables based on the guidelines identified in the previous section. This was done to explore how the system would function from a technological point of view. This research project focuses more on what happens after the collecting of data because there are currently a wide variety of products, such as Fitbits, that do such capabilities.

7.2 Look and feel

As the prime goal of this project was to explore the interaction between the user and the system, an app mock-up was made on Figma. Based on the design guidelines and the insights from the concept, the low-fidelity paper prototypes were developed into
digital screens. This prototype focused on two key phases of Knapp’s relationship stages, Initializing and Experimenting.

In the Initialising phase (see figure 21) the focus was on building an AI with a youthful, friendly and trustful tone to help onboard and inform the user. It aimed to create a relationship with the user that motivated them to keep using the system.

The onboarding begins with the system explaining to the user how it works. The onboarding covers the following (see figure 20):

- The system introduces itself and establishes a friendly personality
- The system explains to the user the kind of data that is going to be collected from the user and surroundings
- Explains to the user how they can customize the system to use it for their benefit.
- Explains to the user how the AI will analyse and find patterns in the user’s behaviour to give them useful insights. Encourages them to constantly interact with the AI agent for more personalized and effective insights.

Next, the system helps the user check and enable the sensing device by taking them through each step from checking the sensors to allowing permissions (see figure 24).

![Figure 24: Setting up the device for ‘Sensing’](image)

The onboarding is followed by asking the user to self-report the extent of their condition through a series of questions taken from a questionnaire recommended by Dr Sudhir Reddy to analyse the type and severity of ADHD in a patient. They are also asked to let the system know if they have been diagnosed with any co-morbid conditions.

Based on results from the self-reports, the system recommends the user the best ways they can use the system, for example, to regulate their stress levels, manage
their schedules, and maintain their comorbid conditions. The user is given the freedom to choose or just skip this step and continue exploring.

The second phase of the prototype was targeted to visualise the experimentation between the user and the system. It focused on encouraging the user to explore the system and get excited by it. It also aimed at creating a bond with the user through trust. This was done by explaining the intent of the system with every decision, to help the user understand its logic and decision-making capabilities (see figure 25). This was done to explore the sensory experiences of using the system and understand the user’s interactions.

Based on the data collected from the user and the user’s preferences, the system provides the user with insights. As shown in figure 19, an example can be insights into the user’s stress levels and co-morbid conditions. With every insight, the user is allowed to understand the system’s logic. They can ‘Talk about it’ with the AI agent via a chat agent (see figure 19). The AI takes the user through every step of its logic, asking the user for their input at every step. These interactions help the AI agent understand its user better. In return, the AI agent over time provides the user with more meaningful insights.

This prototype was tested with users and re-iterated, this will be discussed in the next section.

7.3 Role

The final phase of Knapp’s relationship is the ‘Bonding’ phase, where the system and user are fully integrated into each other’s lives, it was difficult to prototype for this via the app interface. Hence, to help envision the role of the design in the user’s lives, storyboarding was used (see figure 26). This method was used multiple times throughout the process to help understand a user’s day-to-day using the system. It was chosen as it is a concrete representation of the design idea and makes it.
Taking into consideration, all these prototypes, it was mapped on Houde Hill’s model to understand how they represent the design concept. Although different aspects of it cover different parameters, it is still an incomplete representation of the concept. It does not represent the look and feel of the physical device, it fails to explore the intermediate phases and the final storyboard is based on assumptions. Given the time and resources, this prototype attempts to display a holistic prototype which could prove to be a starting point. Hence, this prototype is seen as an ongoing process which needs to be developed further and tested iteratively in the future.

8. TESTING

As mentioned in the previous section, Testing was done with the App Prototype. Two initial stages of the human-system relationship were tested - Initialising and Experimenting. The testing was done with three students from Malmö University suffering from ADHD and the system was also discussed with psychiatrist Dr Sudhir Reddy.

In the initialising phase, the key assumptions made were:

- The tone and personality of the system are friendly, trustworthy and useful
- It gives a detailed explanation of what the system does to help the user get accustomed to a new interaction
- The data visualization was informative to make sure they don’t get lost along the way
- This phase will prompt the user to engage with the system further.

For the test, the users were called to a secluded environment where they felt comfortable. As these stakeholders have been involved throughout the process, they
were given updates about the trajectory of the concept. They were asked to try the prototypes and encouraged to ask questions along the way. They were guided throughout the user journey. Their movements on the screen were carefully monitored and observed. Key insights after the testing:

- The tone and personality of the system were described as trustworthy and helpful
- They faced anxiety and fear when they knew how much data was collected
- The data visualization was too much text and they got distracted along the way
- They were extremely enthusiastic about using the system but needed more of a ‘push’ from the system’s side to keep them engaged for the long haul
- They enjoyed the option of personalizing their goals and expectations

Based on these insights, the prototype was reiterated. The graphics and information were made more visual and less verbose. Reminders were added to help the user stay in contact with the system (see figure 27). Although, the future scope of this project included going deeper into ‘keeping the user hooked’, this is discussed in the next section.

The next stage of the testing included role-playing along with the other methods mentioned above. The users had to imagine having interacted with the system for a while and had put in the time to train it and interact with it. With this state of mind, they were asked to interact with the prototype. This stage also consisted of doing A/B testing to see what type of dialogue the user preferred to have with the system (see figure 21). Assumptions to be tested included:

- Users will use the insights to gain a deeper reflection on their disorder
- Users will trust the system once they see where and how their data is being used

Key insights observed include:

- They were extremely excited about the insights like stress and distractions
- The system established a friendly and trustworthy tone
- Therapy talking points are something they were not interested in as they relied on their therapists to guide the conversation
- Users preferred to use chat-bot style UI to interact with the system as it gave them a sense of two-way dialogue
- Users initially were anxious about the amount of data collected by the system but get comfortable in this stage when they see how their data is being used.

Based on these insights, changes were made to the UI. The scheduling was broken down to two weeks at a time rather than monthly recommendations. Chat-bot UI style was established to help the users converse with the system.
After these changes were made, the system was discussed with Dr Sudhir Reddy to gain feedback on which other stakeholders could be involved and to get his general feedback. As he stays in the United States of America, getting him to test the prototype in person was difficult. Hence, the design was presented to him via Zoom. Here are some important insights gathered from the interview:

- He appreciated the idea and advised on creating ‘shareable reports’ so they can be used by doctors to monitor the patient’s health
- He also was sceptical of such an advanced system existing
- He said giving patients therapy recommendations won’t work because each patient-doctor session is very unique and cannot be replaced by the machine
- He liked the idea of monitoring comorbid conditions, schedules and recommendations to become more independent.

Based on these insights, the prototype was modified to have daily, weekly and monthly reports that could be gathered and shared with doctors and caretakers. The therapy recommendations were removed after feedback from doctors and patients.

9. DISCUSSION

This section will begin with how the proposed concept caters to Interaction Design and then it continues to explore the ethics involved throughout the design process. This section ends with discussing the plans for this design concept.

9.1 Interaction Design Relevance

This design concept is at the intersection of three areas of Interaction Design namely: Personal Informatics, Interactive artificial intelligence and System as a Dialogue Partner (see figure 28).
Figure 28: Interaction Design relevance

9.1.1 System as a Dialogue Partner

As mentioned in the Final Concept section, the relationship was viewed through different interactions specified by Hornbæk et al. (Hornbæk & Oulasvirta, 2017). Initially, after the ‘Define Stage’ of the design process, the system was imagined to behave as a tool where the interaction is mainly about manipulation from the user’s end where the user utilizes the system to perform a certain task. As the concept evolved, it demanded a need for two-way cyclic communication between the user and the system. Here, the user and system are in a symbiotic relationship where they are continuously learning from each other (see figure 13). This transition mainly occurred due to the realization that the system has to be personalized to each user as ADHD is a very heterogeneous disorder which affects different people in different ways. Hornbæk et al. stress that such an interaction demands for the user and the system to understand each other. This is achieved in the concept through constant explanations from the system’s end to encourage open communication and dialogue between the system and the user. The user via the interface teaches the system about themselves. The system in turn updates its knowledge based on its interactions with the user and the data collected. Mapping and feedback are crucial concepts when it comes to designing user interfaces for such dynamics. This is established in the UI where direct mappings were established to help the user translate the intentions into the desired system state with simplicity and directness.

9.1.2 Personal Informatics

Rapp et al. defined Personal Informatics (PI) systems, defined as “those that help people collect personally relevant information for self-reflection and gaining self-knowledge” (Rapp et al., 2018). In this paper, the authors devise user requirements to establish a novel design of a PI system. These user requirements were kept in mind while the concept was being designed. The user requirements are as follows:

- Encouraging the integration of different types of data: This is done in concept by integrating data from different sources such as the environment, physiological data and trained data gathered from ADHD-related research.
- Supporting users in remembering their data: This is done in the concept by giving users the agency to view their insights and go into the
details regarding the system’s decisions with that insight. It explains what data was collected and how the system made sense of it.

- Supporting users in identifying with their data: This is done by collecting contextual data and giving insights that are personalized by the user itself.

- Offering different views on data: This is done by giving users the option as to how deeply they want to understand the system. They can either just view the insights or converse with the system to understand its decisions.

- Highlight data correlations: This is very clearly seen in the design, gathering insights and efficiently visualizing them instead of bombarding the user with figures and numbers.

Furthermore, two additional design considerations stated in the paper were adopted to make the system a better PI system. This included:

- Sociality: Allowing the users to share their data with necessary stakeholders like therapists and family members.

- Design for personalization: Allowing the users to choose what they want to get out of the system gives them agency and empowers them.

The future plan for this concept includes adding other design considerations such as Behavioural change from the users’ end and Designing for connection. This is explored further towards the end of this section.

### 9.1.3 Interactive Artificial Intelligence

Due to semantic relevance, time constraints and availability of resources, a decision was made to focus more on the interaction between the user and system rather than on building an efficient AI. Looking at this system from the AI’s point of view, it gets its information from three different places namely: the user, the designer and the context. Designing such an efficient AI comes with certain ethical considerations. IEEE’s Ethically Aligned Design (IEEE, n.d.) and IBM’s Trusted AI (IBM, n.d.) ponder on such issues. Based on this, five focus areas were identified:

- Answerability
- Value Alignment
- Intelligibility
- Equity
- Human Data Rights

These are discussed in detail in the next subsection about the design concept.
9.2 Ethical Considerations

As intelligent systems are growing rapidly, it is important to consider their ethical implications. As designers, it is important to consider such ethical considerations throughout the design process. This section will go into detail about the five focus areas explained above.

9.2.1 Answerability

It was important to show accountability for the vast amounts of data shared by the users. Even though one cannot personally be held accountable for how the data is used by stakeholders, it is important to consider the ramifications of such technologies. Although due to time constraints it was not possible to dive deep into the repercussions of AI systems, it is one of the first steps involved in future work.

9.2.2 Value Alignment

As a designer, it is essential to consider the values and norms of people of different cultures using this. It was essential to bring in experts such as psychiatrists and academics to understand the values of people with ADHD across different cultures. While designing personas and interviews, this was constantly kept as a consideration. It was important to include experts and patients at every iteration to understand their needs, goals, values and capabilities.

9.2.3 Intelligibility

As a designer, it was important to design an AI that users can perceive easily. It was also important that the users understood the decision-making process. This was by giving users the agency to access as much information as they need from the system, it was essential for them to understand everything to fully trust the system. This practice was conceptualized in different versions for the user to try and the design was reiterated. This is what made most users feel empowered.

9.2.4 Equity

It is always important to minimize bias and increase inclusive representation all through the design process. Open dialogue was established with users to comment if they felt any sort of biases during workshops. The users chosen were also of different nationalities and genders, this was done to ensure the design solution is as inclusive as possible.

9.2.5 User Data Rights

It was important to make sure the user felt safe while revealing sensitive information during workshops. All of them were made to sign consent forms. This was also the reason why no images of workshops and interviews have been shared, it was to keep their identity anonymous. Even in the design concept, the users have full control over the data they want to share and the permissions. Permissions can be turned off at any point by the user.
9.3 Future Work

The current concept is viewed as a handoff to future stakeholders like Malmö University, therapists and patients. This system will be further explored with research expert Mona Holmqvist in how it can be adapted for students suffering from other neurodevelopmental disorders like Autism. Important directions to explore in the future work of this system include:

- Understanding the ramifications of such systems on society
- Designing a physical wearable that will be used for ‘Sensing’ data
- Continued testing of existing system on users to understand how to design for the next stages of Knapp’s Relationship Model
- Learning how to code and develop such complex technologies to explore them in real-world scenarios

10. CONCLUSION

This project focused on designing an assistive technology that provides a personalized interactive experience to the user. It is an AI-based system that captures contextual data, analyses it to find relevant patterns in user’s behaviour, and visualizes it effectively to provide students with ADHD with insights into the parameters influencing the nature of their disorder. The design process followed is an iterative double-diamond with a focus on co-design methods. The key stakeholders in this project include Students suffering from ADHD, Disability Services at Malmö University, and Mona Holmqvist – an expert researcher at Pedagogy with a focus on neurodevelopmental children, and medical professionals.

10.1 Adaptability

The proposed system adapts to different requirements of the user at different stages of their relationship. Building their relationship step by step gives the system and user time to adapt to each other. Using Artificial Intelligence as technology enables the system to provide a personalized experience to the user.

10.2 Agencies

Alex adds a new layer of agent design, by giving control to the students suffering from ADHD from the very beginning of their relationship. It allows them to set expectations of the kind of assistance they require. It adapts to the user’s needs over time and allows for flexibility. It gives the user an opportunity to self-reflect on their disorder in order to empower them and make them independent.
10.3 Trust and Reliability

The entire design process is focused on building a system that the user can trust and rely on for various reasons. The relationship between the user and the system is built stage by stage to make sure the user feels comfortable sharing their data and trusting the system to provide them with appropriate insights. The system’s intentions are constantly communicated to the user to make sure the user is completely aware of the system’s intentions.

Following a methodology where expert opinion was considered at every stage to make sure the final outcome is user-centred for students suffering from ADHD. The project included in-depth user research together with the university, psychiatrists and experts. The final prototype was tested with students suffering from ADHD at Malmö University. The final prototype is not seen as the final design but rather an ongoing design process and collection of learnings of designing for students with ADHD.

Having students with ADHD at the centre of the design process, and their needs, wishes, and preferences as a priority, Alex aims to be an example of how AI-based self-reflective solutions can be the future of personalized assistance that can be given to people suffering from Neurodevelopmental disorders.

11. ACKNOWLEDGEMENTS

I would like to express special gratitude to my supervisor Henrik Svarrer for all his help and support throughout the project.

I would also like to think Mona Holmqvist, Eunice Moon and Dr Sudhir Reddy for their time and patience during the course of the research project.

I am also grateful to all the participants for their inspiring insights and enriching interviews and workshops.

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Appendix

Workshop material – Documentation of the questions and tasks asked of the participants

I am an Interaction Design master’s student from Malmö University working on my thesis project. I am trying to use tools like AI to help people with ADHD to get a better understanding of their condition. This survey would take less than 10 mins and it would mean a great deal to me.

I am not collecting any of your personal data or information, and even the information you provide here will only be used by me and not seen by anyone else.

Let’s get started! :)

1. Track yourself doing an activity, it could be anything or it could be you describing an activity from the past (university-related/ hobby/ work-related)

2. Be aware of yourself and your environment

3. Take time to document the following questions

   - Describe the activity in a sentence (E.g.: I had an assignment due tomorrow, it was a 1000-word essay)

   - The time you took to finish the activity

   - Tools used to do the activity (E.g.: Google Docs, Pen Paper)

   - Describe your physical environment in keywords (E.g.: University library, quiet section, there were 4 people around, it was a bright sunny day)

   - If you did get distracted, please mention what trigger(s) distracted you from your task (E.g.: My neighbour was playing music, I ended up watching a new movie on Netflix) *It is completely all right if you are not able to pinpoint what distracted you, just say ‘Nil’

   - Do you seem to realise if you ever get hyperactive? What physical reactions do you have? (E.g.: fidgeting, sweating, restlessly walking)

   - On this scale (1-5), mark how open you are to technologies like AI to understand the parameters influencing the nature of your disorder to support you in gaining insight into your own conditions.