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BACHELOR THESIS

Development of a companion app for university students to promote mental health during periods of solitary home studying

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Declaration of Authorship

I hereby declare that I am the sole author of this bachelor thesis and that I have not used any sources other than those listed in the bibliography and identified as references.

I further declare that I have not submitted this thesis to any other institution to obtain a degree.

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Abstract

Taking into account the growing prevalence of mental health problems amongst university students and an emerging field of research, artificial companions, this thesis aims at developing a solution to combine these two to build a mental health promoting companion for university students. After having built a solid theoretical foundation for this interdisciplinary thesis, which defines mental health as a positive state of mind that enables people to thrive in life and highlights the relevance of the adaptive and engaging traits of artificial companions, a comprehensive concept for the design of such a companion is presented. With the intention to build an artificial companion that closely relates to the users, ethical aspects are of central importance and hence, a special emphasis is put on these aspects within the design. Ultimately, a prototype for the designed concept is developed that implements the core elements of the proposed design concept. The prototype is being tested in terms of functionality of the core components. Furthermore, the system is being tested in the intended setting it was designed for: During sessions of solitary studying. The insights gained from both the theoretical foundations as well as the evaluation process are presented. Last, but not least, directions for future research needed for the improvement and further development of the prototype are outlined.

Keywords

Affective computing, artificial companions, mental health, university students, human-computer-interaction, emotion recognition, ethical design, state machine pattern, mobile application development

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1 Introduction

The present work draws its inspiration from two sources: First, the author's enthusiasm for affective robots and second, the worrying situation of students' mental health, which has increasingly come to the author's attention in recent years.

First, let us talk about affective robots: these are "robots that can recognize, interpret, process, or simulate human affect" [98]. The goal of building affective robots is to build empathetic machines that can react to their users in an emotionally intelligent way and therefore communicate with users more naturally [100]. Therefore, affective robots are preferable to other robots in any scenario in which they need to interact with humans, not only but also, especially in the areas of care, education, service, and companionship. Especially for the elderly and children with special needs (e.g. autistic children) a variety of such affective robots have been developed as a companion to prevent feelings of loneliness or support them in challenging tasks or situations [16, 39, 53, 74, 91]. One might now find this development worrying and argue that human companionship is preferable over robot companionship - especially because affective robots are not able to offer companionship and support in all the ways a human could do [14, 102]. But in the current situation in many western countries, where there are more and more people in need of support and not enough people who can provide it [5], receiving help and companionship by an artificial being might be better, than not receiving this support at all. This is where artificial companions become relevant: They might be reduced to a certain number of tasks they can support with, but they are reachable 24/7 and designed to accompany people in specific stressful or mentally challenging situations.

Now to the second point, the worrying state of student mental health: When the author started studying with her first bachelor's programme in 2011, this was hardly a topic of public discussion amongst students. Climate change was already an issue, but it was not taken as seriously as it is today and therefore did not cause as many concerns about the future as it does today. Living costs were relatively moderate, a worldwide pandemic would have been unimaginable, and wars were so far away from Europe that fear of war in one's own country was nothing to worry about in everyday life for a student. Neither the large number of refugees nor the following right-shift of the political environment in Germany were foreseen. Back then, the primary concerns for most students were passing exams, organizing social activities, and occasionally contemplating future career plans.

Now, 14 years later, the world seems to have changed, and young people are worried about their future on this planet [4]. This is in part due to the climate crisis, which intensified during the last decade [41, 96] but also for other reasons. Following the influx of refugees in

2015, the right political wing received much interest in many European countries [25, 84]. The political landscape in general became increasingly polarized as society struggled to agree on the best way to handle the situation [84]. This became even more notable when the COVID-19 pandemic emerged in 2020, leading to severe restrictions on everyday life for people all over the world. For almost two years, people had to isolate themselves almost completely. Besides having huge impact on the economic situation, this social isolation lead to a worrying increase in mental disorders in adolescents, especially with regard to depression symptoms and suicide rates [30, 46]. Adding to all of this, the Russian invasion to the Ukraine worsened the global situation even more, as it lead to another disruption on global markets, increase in commodity prices and an aggravation in global political and potential armed conflicts [38, 54]. To conclude it all: With the global challenges and conflicts the human population is currently facing, there is much one can reasonably worry about, and it is unsurprising that the occurrence of mental health issues in society has increased significantly during the past years [35, 116]. This circumstance is one that the author not only observed in statistics, but also in her direct surroundings. Talking to other peer students revealed that many of them suffer from mental health problems such as depressive symptoms, negative attitude toward the future, low self-efficacy or problems with organizing one's own life, pursuing goals and meeting the demands of their studies while also taking care of themselves (e. g. exercising, eating well, getting enough sleep). This subjective impression is also well supported by a health survey that was conducted at the University of Applied Sciences Hamburg in December 2022: It revealed an urgent need to act with regards to mental health issues, as almost half of the students who answered the questionnaire showed clinically relevant symptoms of a depressive disorder, and more than half of the respondents showed clinically relevant symptoms of generalized anxiety disorder [9].

As a result of the perceived urgency to find solutions to promote student's mental health and the enthusiasm for affective computing[1], the author developed the idea to create a companion, which supports students in caring for their mental health. Having made the experience that caring for one's mental health is especially difficult during phases of solitarily studying at home, when there are many tasks to do, no one to talk to, and no external supporting factors such as a lunch break offered in the cafeteria, the idea was born to develop a companion to support students who need to solitarily study at home, for example, while doing homework assignments, preparing for an exam or writing a thesis. This companion then could offer company to the solitarily studying students, track their mood, and initiate

[1] The term *affective computing* was proposed by Picard [87] and is nowadays used as an umbrella term for the recognition and analysis of human emotion, sentiment and feelings and the development of computers which intelligently respond to these. [107].

supportive interactions in case it detected the student might not be feeling well or simply forgot to take a break.

This work is a documentation of the whole process of putting this idea into practice. It begins with a comprehensive chapter on the two core concepts, which the thesis deals with: mental health and artificial companions. The theoretical background is explained together with a view on related academic works that deal with the topic. After having laid this theoretical foundation, the practical part begins: First, all the aspects that need to be kept in mind when designing such a mental health promoting artificial companion are discussed. From the theoretical findings, a list of requirements is derived. Based on this list of requirements, the technical design for the companion is illustrated and the inner logic of the software design is explained. The next chapter, the implementation of the designed concept, explains which parts of the concept could be realised within the scope of this thesis and points out which aspects needed to be left aside for the first prototype. It also gives an overview of the implemented architecture and the communication between the different modules within the application. As testing is essential in any software development process, the conducted tests and their corresponding results are discussed in the following chapter. Finally, the work is concluded and an outlook on future work is provided.

The author wishes you, as a reader, fun and interesting insights while reading this thesis. Please note that, despite this is primarily an academic piece of work with the intention to achieve a bachelor's degree in computer science, it is also the documentation of the author's personal journey to create an envisioned piece of software from scratch. To make this feelable, the chosen tone might be sometimes less formal – but always well-grounded, open-hearted, and thoughtful.

2 Theoretical background

In the preceding chapter the motivation of the author to create a mental health companion for university students was discussed. Before addressing design considerations, it is essential to outline key theoretical concepts in any scientific work. This chapter will fulfil that requirement. Given that the aim of this thesis is to create a companion app to promote mental health, the core concepts to be examined are mental health and companions.

2.1 Mental health

2.1.1 Definition of mental health

At first sight, it might appear trivial to define mental health. As the term suggests, this could mean that one is mentally healthy and therefore does not suffer from any mental illness. However, as detailed by Gautam et al. [2024], the concept is notably complex. Definitions vary widely, with some being simple, focusing on only of a few aspects [113], while others conceptualize mental health through a multifaceted lens [13, 37]. The challenge of defining mental health is intensified as it is sometimes regarded as synonymous with mental well-being [113], while other authors argue those concepts are distinct [40, 45]. Additionally, conflicting definitions can even emerge within the same source [114].

Considering the nature of this thesis within the domain of computer science, it is determined that an in-depth exploration of the social sciences' discourse on the distinctions and similarities between mental health and mental well-being is unnecessary. Thus, in this thesis, the commonly accepted definition by the World Health Organization (WHO) for mental health is adopted. According to the WHO, mental health is defined as:

> "a state of mental well-being that enables people to cope with the stresses of life, realize their abilities, learn well and work well, and contribute to their community" [114]

Mental health, as defined, encompasses not just the absence of mental disorders, but also an individual's ability to deal with life's challenges without experiencing excessive stress, adverse mental states, or risk of self-harm. The WHO states that this is not only a basic human right, but also "crucial to personal, community and socioeconomic development",

because mentally healthy individuals are better able to "connect, function, cope and thrive" (see Figure 1). [114]

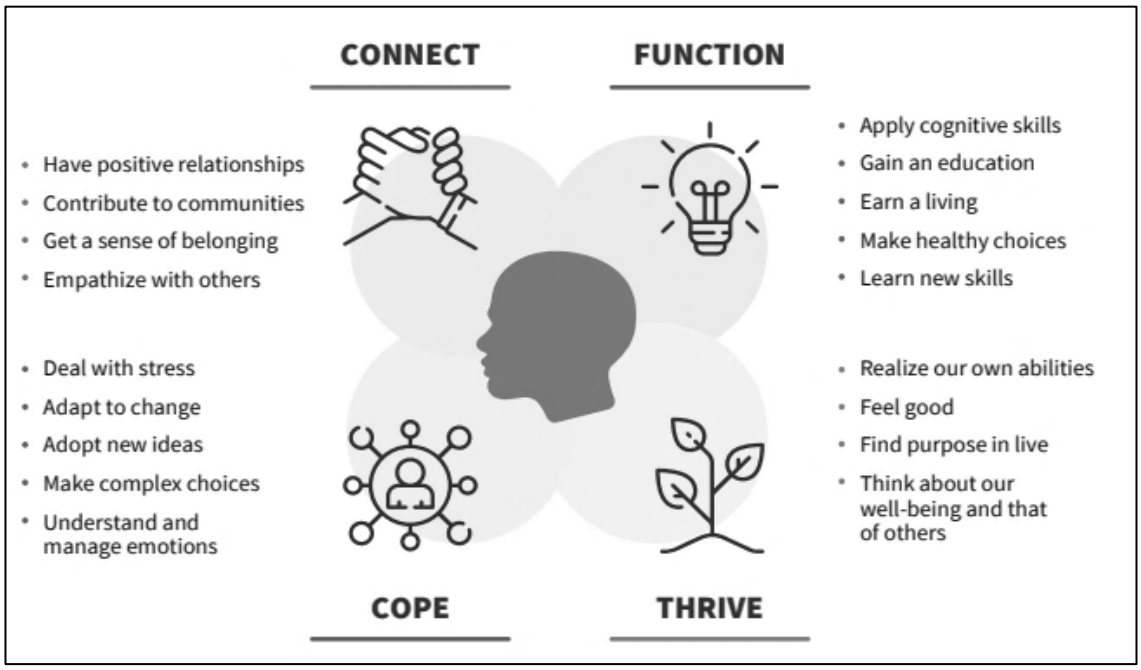

Figure 1: The intrinsic and instrumental value of mental health [121]

The application of this mental health concept to university students can be concisely described as follows:

Mentally healthy students…

… experience a general sense of wellbeing

… feel confident in their own abilities

... can manage their emotions in a healthy way

…can cope with daily academic stressors (e. g. homework, writing assignments, exam preparation), as well as broader life stressors (e. g. low income, insecurity about the future) in a positive way

…can maintain concentration when needed, therefore being successful in gaining new skills and knowledge

…find time to build and maintain positive relationships

…feel a sense of purpose in what they are doing

As illustrated in the prior list, mental health encompasses various aspects, with numerous influencing factors. These will be analysed in the subsequent section.

2.1.2 Factors influencing mental health

The WHO [2022] states that mental health "is determined by a complex interplay of individual, family, community and structural factors that vary over time and space and that are experienced differently from person to person". Figure 2 gives an overview of the protective factors that determine mental health:

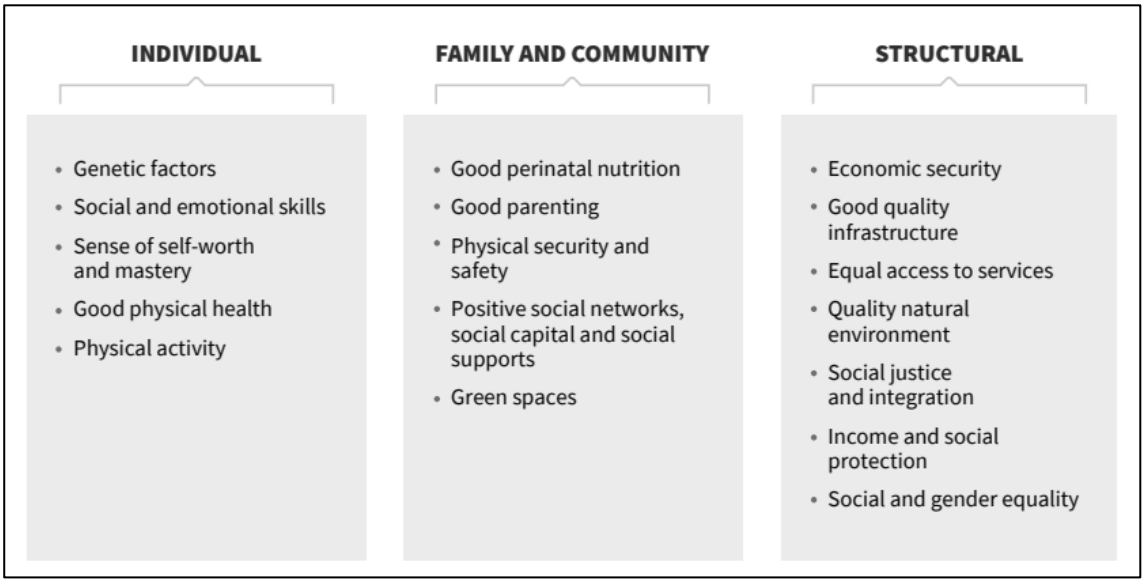

Figure 2: Examples of protective factors that determine mental health. [121]

Many of the factors discussed, such as genetics, perinatal nutrition, parenting, and structural influences, are beyond a student's control. But despite the variation in individual "starting conditions" concerning mental health, there exist certain factors that can be influenced by everyone regardless of personal starting conditions:

- Social and emotional skills
- Sense of self-worth and mastery
- Physical health (with restrictions on chronic diseases)
- Physical activity
- Positive/supportive social networks

Individual backgrounds can make it easier or harder to develop certain factors. For example, if someone did not learn sufficient social or emotional skills in childhood, it could be a great challenge to learn these skills in late adolescence. Similarly, an individual's physical health and activity levels are influenced by how they were raised. An individual who has been accustomed to unhealthy dietary practices during childhood and has consequently developed severe obesity may encounter considerable challenges in altering these habits and initiating consistent physical activity.

However, unlike the structural factors, which have been mentioned earlier, those are the factors in which everyone can theoretically engage. Consequently, the development of the mental health companion concentrates on these factors.

2.1.3 Mental health supporting interventions

The previous subchapter discussed factors positively influencing mental health. However, these factors were discussed in broad terms without offering explicit guidance on actions individuals should take to enhance their own mental health. This chapter aims to identify specific interventions to improve mental health.

For clarity and efficiency in the exploration of scientifically validated interventions for enhancing mental health, the terms "mental health" and "mental well-being" were utilized alongside "interventions," "improve," and "promotion." As explained in chapter 2.1.1, mental health is defined as "a status of mental well-being." Therefore, differentiating between the two terms when researching for potential mental health-promoting interventions may unnecessarily limit the scope of possible findings at the outset. As an initial point of research, Google Scholar was utilized. Upon finding notable articles, the author conducted a backward citation search for further topic exploration.

However, the use of the techniques mentioned above did not yield concrete results. Most of the articles are written in very general terms [90, 106, 115]. For example, they claim that cognitive behavioural therapy (CBT) and mindfulness-based strategies aid in enhancing mental health, yet fail to specify which mindfulness strategies were confirmed effective [115]. Given the diverse range of mindfulness-based techniques, it remains uncertain which is most effective for enhancing mental health.

To address this query, the study was expanded to include a standard Google search. Resources like mentalhealth.org.uk [75] and academic guides on studying while maintaining mental well-being [13] were helpful in identifying concrete interventions that could be proposed by the companion. The following is a non-exhaustive list summarizing the most recommended mental health interventions, with sources indicated in parentheses:

- Physical activity [32, 40, 75, 106]
- A healthy diet [40, 75]
- Sleeping adequately [40, 75]
- Spending time in nature or green spaces [15, 75]
- Staying connected to other people, for example, by talking to trusted friends or family members or participating in some community project [40, 75, 106]
- Self-soothing techniques such as meditation, journaling, breathing exercises, reading, creative arts, listening to music [32, 40, 65, 70]

- Practising positive thinking and gratitude, for example keeping a gratitude journal, finding good in a bad situation, caching negative thoughts and replacing them with positive ones [40]
- Plan joyful activities to look forward to when life is tough and execute them [40, 75].
- Emotion ventilation[2] [11, 40]
- Being kind [20, 75, 101]
- Being curious and open to new experiences [75]
- If there is a specific problem that causes problems with mental well-being, use problem solving skills to directly tackle the problem, such as gathering information, seeking advice, talking to trusted people, accepting help [40, 75]
- Avoiding behaviours that are known to harm mental health, such as addictive behaviour or drug abuse [75, 106]

An observant reader may recognize that the list primarily provides "categories" with instances rather than specific interventions. This is accurate. Once these intervention categories were compiled, further investigation was needed to identify practical, concrete examples for each. Therefore, the author conducted further research on the internet to generate ideas since the initial research did not produce tangible outcomes.

The complete list of example interventions for the mental health promoting companion application, along with their respective sources, is provided in Appendix 1. It consists of 40 interventions in total, covering almost all the categories from the list above – except for "avoidance of harming behaviour", "emotion ventilation" and "problem-solving strategies". This is because the aspect of ""avoidance of harming behaviour" primarily pertains to individuals engaging in harmful actions, and altering such behaviour is more of a general concern rather than an activity that could be done during a brief study break to enhance mental health. The same goes for problem-solving strategies: These are only relevant, if somebody has a concrete problem to solve and cannot be used as an example for a mental health promoting intervention. Finally, emotion ventilation is only feasible, when a person is experiencing intense emotions and has someone to share their feelings with. While the role of listening to the user can be fulfilled by the companion, this cannot be seen as a specific intervention. It is more a general functionality of the companion. Thus, the previously mentioned categories seem inapplicable for the example mental health supporting intervention list. Instead, only categories with clearly defined and feasible interventions were included.

As finding suitable intervention examples was easier for some of the categories, the examples are not evenly distributed across the categories.

[2] Emotion ventilation is the "full and free expression of feelings or emotions" [3].

2.2 Artificial companions

2.2.1 Definition of artificial companions

Defining artificial companions could have also been a challenging due to numerous existing definitions over the past 22 years [92]. But fortunately, Rogge [2023] conducted a systematic literature review on artificial companions. Her article provides a thorough overview of various definitions and design concepts and proposes a unified definition that combines the key aspects of these diverse definitions. According to this definition, artificial companions are:

> "social agents characterized by adaptive and engaging social design pursuing emotional bonds with their users" [92].

Within the following paragraphs the different elements of this definition will be further examined.

Social agents: The term agent is widely used within the field of computer sciences. While it is intuitively understood as a kind of "acting entity" (deriving from its Latin word origin: "agere", which means "to act") [110], there are various, heterogeneous definitions of this term within the research community [79]. As Weiss et al. [2010] point out, the concept originated from the field of artificial intelligence, especially agent and multi-agent systems, but it has also been in use within social sciences in the context of agent-based modelling [28].

There are various classifications for agents, e. g. Russel and Norvig [2016] have established a distinction made up of five categories reaching from very simple reflex agents to intelligent learning agents. In the more recent literature, there is a distinction between two notions of agents that have become popular. This is the differentiation between so called weak agents and strong agents. Following Weiss et al. [2010] a weak agent is: "a self-contained software/hardware unit that can handle its tasks in a knowledge-based, flexible, interactive and autonomous way". This means it can handle both reactive as well as proactively, it can interact with its environment and within the realm of its task, it can decide predominantly autonomously without needing to consult third parties priorly. A strong agent is not an agent "stronger" than the priorly mentioned weak agent, but it is an alternative to this concept. Following this approach, an agent is "a (hardware/software) unit that, analogous to people, possesses mental attitudes or states". There are different kinds of states that are relevant for an agent in the strong notion, for example information-related states such as knowledge or assumptions, connotative states such as intentions or duties, affective states such as goals or preferences and last, but not least, emotional states such as joy, surprise etc. Both definitions focus on different aspects of an agent, so they can be viewed as complementary perspectives that together give a more comprehensive understanding of the

agent concept. Therefore, both notions will be considered within this work, when we now have a look at the more specific term social agent.

The term social agent is frequently used within the field of affective computing, yet rarely explicitly defined [33, 97, 109]. As a result, finding a predominant definition for this concept was not successful. To resolve this issue, some of the existing definitions will be discussed within the next paragraphs and consequently, the basis for understanding social agents within the scope of this thesis is explained.

Firstly, a social agent can be an agent (as defined above) with a focus on social competency. This is suggested by Weiss et al. [2010], who explain that the term agent is often used in a modified form which intends to "underscore the most important attribute of the respective agent" [108]. They name examples such as autonomous agent, cooperating agent or adaptive agent. Similarly, a social agent could be interpreted as an agent which most important attribute is being social, therefore focussing on social interactions and behaviour.

Secondly, social agents can be defined as "cognitive entities that reason about and interact with one another", as stated by Foo and Peppas [2007]. Same as with the term "agent", the term "social_agent" is often used within multi-agent-system or agent-based simulation research, where agents must socially interact with one another. While this aspect is not central to this thesis, it is still relevant to consider when aiming to define the concept comprehensively.

Thirdly, social agents may be defined as Dautenhahn [1998] describes them, as "social intelligent agents". While her definition partially overlaps with the one from Foo and Peppas [2007] with respect to the fact that they behave socially and interact with other agents, the author takes a step further and puts a special emphasis on the aspects that need to be kept in mind in the creation of socially intelligent agents, like "storytelling, empathy, embodiment, and historical and ecological qrounding", which, from the Dautenhahn's view, can contribute to increase believability of the agents and improve the relationship between humans and agents. [23]

Putting together the knowledge from the various sources, within this thesis the term social agent is understood as follows:

> "A social agent is a self-contained hardware or software unit which can autonomously engage in social interactions and social behaviour – either with other social agents or with humans. Analogous to people, it possesses cognition, empathy, relevant knowledge about the situational context, mental attitudes and can flexibly react within and across different social situations."

With this comprehensive definition the author hopes to prevent the shortcomings of other studies, which have used the term "social agent" without explicitly defining it. It combines both the aspects of weak and strong agents from Weiss et al. [2010] as well as the focus on social interactions, which is inherent in social agents. Furthermore, it includes both types of social interactions that are possibly relevant in the social agent research: the interaction of social agents amongst each other, and the interaction between social agents and humans. Lastly, it includes the importance of including human-like aspects in the creation of social agents such as cognitive capabilities, empathy and knowledge of the situational context which has been emphasized by Dautenhahn [1998].

So, now that the reader knows what a social agent is, there are still three parts of the definition of an artificial companion from Rogge [2023], which need further explanation: adaptive and engaging design and the pursuing of social bonds with the users. As they form the next part of the definition, the terms "adaptive design" and "engaging design" will be explained next.

Adaptive design: In her review, Rogge [2023] identified adaptivity as one of the two key characteristics of an artificial companion. It enables the agent to react to the user and its environment. In a very basic way, it is shown when the agent is looking at the user or reacts to the user's actions. In a more sophisticated way, adaptability is shown by an agent, if it adapts its behavior based on the user's preferences and needs. Agents with very high adaptability can additionally adapt their behavior based on the current situational context, e.g. by choosing the right communication style based on the user's emotional state. The general goal of the adaptive design is to create personalized interactions to make the companion fit better to subjective user expectations and therefore increase the acceptability of the companion. [92]

Engaging design: The second key characteristic mentioned in Rogge's [92] definition is engagement. As she points out, recent studies have shown that long-term human-machine interaction cannot be successful without an engaging design. This means that the artificial companion needs to approach the user on an emotional level and initiate interactions, as well as resume to interactions at a later point in time. Simple forms of engagement are e.g. greeting the user and reacting positively towards the presence of the user. More complex forms of engagements include tying in with previous interactions to evolve the interaction to a relationship. To evoke positive emotions in the user, the artificial companion needs abilities to display emotions, both on a verbal and nonverbal level.

The last, but far away from least part of the definition of an artificial companion is the pursue of emotional bonds with its users. What this means and why this is so important for the companion will be explained within the following paragraph.

Pursue of emotional bonds with the user: As Rogge [2023] points out, the design of an artificial companion pursues emotional bonds with the user. This is already to some extent explained by the two priorly mentioned key characteristics adaptivity and engagement. But although this is already included somehow in the two previously mentioned points, she thought it was important to explicitly name this goal within the definition of an artificial companion.

The reason for this is that Rogge [2023] assumes that an artificial companion cannot really be "produced", but only exist in the perception of the user. So, when a social agent is designed with adaptive and engaging behavior, this is still only a social agent. But, over time, when the connection between the social agent and the user grows stronger, the user might start to perceive it as a companion (see Figure 3). Therefore, seeking this emotional bond with the user is crucial for the design of any agent that is aimed to become an artificial companion. [92]

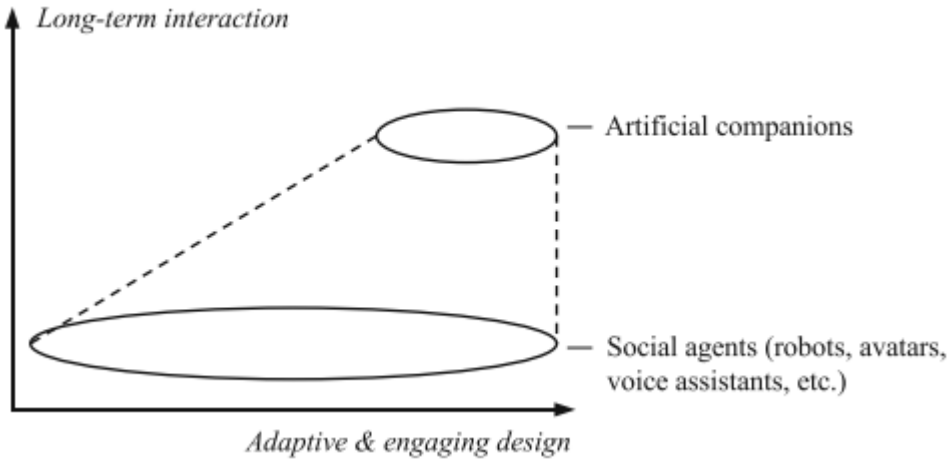

Figure 3: Illustration of the assumption that some agents become artificial companions through the course of long-term interaction and based on their social design [65]

To sum this up, within this thesis an *artificial companion* is defined as a social agent characterized by adaptive and engaging social design pursuing emotional bonds with its users. This means, it is a kind of autonomous acting (hard- or software) entity with a focus on natural and social interactions with its human users that tries to build up long-term relationships with its users by showing both adaptive and engaging behavior and communicating in a way that is intuitively understood by humans.

2.2.2 Central design aspects for artificial companions

Within the last subsection, it was explained extensively what an artificial companion is. To facilitate the design process in the following chapter, within this subsection the most important design aspects for artificial companions shall be highlighted.

Rogge [2023] identified five features, which can be seen as most important for the creation of an artificial companion:

1. **Communicational Skills:** The ability to communicate with the user is probably the most important feature of any companion. It does not only set the basis for an interaction with the user, but also for the companion's status as a social entity. As users prefer a natural, human-like communication style that can be understood intuitively, an artificial companion shall be able to communicate both verbally and nonverbally. Therefore, using spoken language and understanding it are key features a companion should have. Furthermore, it should use some kind of nonverbal clues like gestures or mimics to support the spoken language, show appropriate emotions and appear livelier and more authentic. Another feature mentioned by Rogge [2023] in this context is the use of eye-contact: To signal attention to the user and promote social connectedness, the companion should look at the person speaking to it, but also include some passages of occasionally looking around or simulating to daydream. This behavior is likely to be perceived as "natural" and human-like and does prevent the companion from being perceived as uncanny[3].

2. **Adaptivity**: As adaptivity is one of the key characteristics for an artificial companion, it is crucial to include this as a feature in the design of the agent. In her work, Rogge [2023] distinguishes between adaptivity to user and adaptivity to context, but for the sake of clarity, those two aspects will be explained together within this paragraph. Adaptivity towards the user starts with distinguishing different users and knowing their names but does not end in this: More advanced companions also show empathy to the user by predicting and reacting adequately to the user's emotional state. Furthermore, they start self-initiated learning process and gather relevant information on the user with each interaction, so that the interaction with the user becomes more personalized over time. As an example, the companion could learn the user's sense of humor or develop a personal greeting ritual together with the user. To be able to adapt appropriately in various user and contextual situations, the artificial companion needs various recognition

[3] This is only one example of the reasons why an artificial companion might be perceived as uncanny. For more details, see Embodiment and Appearance (p. 15) – There, this effect is explained in more detail.

capabilities, data storage and data processing skills as well as knowledge about social and cultural norms, values and habits. To adapt properly to the situational context, the companion needs to continuously analyze its environment. As data-privacy concerns might limit the willingness to interact with an artificial companion, adequate data management that guarantees the security of personal data is inevitable for a reliable design of an artificial companion.

3. **Engagement**: The second key characteristic of an artificial companion mentioned in the definition by Rogge [2023] is engagement. This means that the agent not only behaves as a passive entity but also tries to proactively initiate interactions with the user – therefore "engaging" in a user interaction. This can, on the one hand, mean that the companion tries to become a part of the user's activities, for example via making suggestions for pleasant activities, sharing ideas or motivating the user. On the other hand, it can mean that the companion tries to include the user in its own activities, e.g. by asking for attention or help. To be able to proactively connect with the user, the artificial companion needs to be able to display emotions and intentions in a way the user can understand them (as mentioned above). In an educational or therapeutical setting, the companion might also need recognition capabilities to monitor the user's mood and engagement to adapt its behavior to keep the user on board. One ethical concern mentioned in this context is the risk of social isolation of the user, which may result from the user preferring interactions with the artificial companion over interactions with real humans. To prevent such unwanted consequences the artificial companion can serve as a mediator of human-human interactions, for example by encouraging the user to contact friends or supporting interactions between users at home [80, 92].

4. **Personality**: This is a feature that has not been mentioned in the definition but has been mentioned by several authors as a key characteristic for artificial companions. One quote that sums up the relevance of personality for an artificial companion is the following by Banyon and Mival [2013]:

> "[a]s soon as interaction moves from the utilitarian to the complexity of a relationship, people will want to interact with personalities that they like"

Putting together the clues from various sources of research, Rogge [2023] found out, that authors tend to use established psychological models, which were originally only used for humans, to describe the artificial companion's personality. The following personality traits seem to be recurring amongst different authors, when describing an ideal artificial companions personality: "humor, talkativeness, friendliness, cooperativeness, trustworthiness, empathy, responsiveness, proactivity, predictability, and

controllability" [92]. Although predictability is one of the character traits mentioned that an artificial companion should have, some authors also suggest including unexpected behavior to some extent to prevent habituation effects that might bore the user and lead to rejection of the artificial companion. Negative connotated behavioral patterns such as "patronizing, hostile, dominant, or cynical behavior" [92] should be avoided when designing an artificial companion.

5. **Embodiment and Appearance**: While it is theoretically possible to create an artificial companion without any form of embodiment, most of the papers suggest at least some form of physical appearance. Being physically present supports both communication with the user, as it makes it possible for the companion to add a nonverbal expression to the communication, as well as the emotional bond towards the user, since it is easier for the user to perceive the companion as a social entity [92]. Regarding the form of embodiment, Rogge [2023] makes clear that the external appearance must match the intended purpose of the companion. For example, an animal-like robot might not be perceived as serious coach in an educational or business context. Therefore, the outer appearance chosen (mostly it's either animal-like, human-like or thing-like/abstract) must be appropriate for the desired application context. While researchers agree that an anthropomorphic outer appearance is in general desirable, since it makes human-machine interaction more intuitive for the user, it must be kept in mind that too high orientation on a human-like appearance might create aversion towards the companion due to the uncanny-valley-effect[4]. Last, but not least, all artificial companions in the studies reviewed by Rogge [2023] seem to share certain characteristics of their external appearance: the use of white or light colors, big eyes, large heads and round body shapes. All these aspects together make up a design aiming to be non-threatening and eliciting positive affects and a social response from the user by being perceived as cute.

This section was about how a social agent should be designed to become perceived as an artificial companion. Based on the definition provided in chapter 2.2.1, an artificial companion is a social agent which aims at building emotional bonds with its user. The five design features explained within this section, namely communicational skills, adaptivity, engagement, personality and embodiment, directly relate to this goal. They aim at making communication with the user as intuitive as possible and creating a believable character, so that

[4] Uncanny Uncanny-Valley-Effect: Describes the effect that robots become more appealing, the more they appear more humanlike —but only up to a certain point. Upon reaching that point, called the "uncanny valley", a person's affinity descends into a feeling of strangeness, unease, and a tendency to be scared or freaked out. [69].

the user perceives the artificial companion as a social entity and builds a relationship with it.

2.3 Related work on mental health promoting companions

The last two chapters examined the concepts of mental health and artificial companions. It became clear that mental health is more than the absence of mental illness (it is indeed more a status of mental well-being and thriving) and that artificial companions are social agents, which design simplifies user interaction and is aimed at building social bonds with the user, which in turn, makes them be perceived as social entities relevant to the user.

The aim of this thesis, to bring this back into the reader's mind, is to create an artificial companion to support university students with their mental health in phases where they have to study alone from home, for example while preparing for exams, writing term papers or in the unfortunate event of another pandemic. Before the concrete practical implementation of this project is discussed in the next chapter, we will first take a look at the current state of research and related work within the area of mental health companion apps and solutions to improve university student's mental well-being.

As far as the author knows, there are no existing works with a similar approach. Nevertheless, the idea of creating a (mental health) companion app for university students, is nothing new. This topic (more or less closely) has already been addressed by other students, academics and researchers. For example, Kahn et al. [2021] wrote a thesis in which they developed a smart companion agent for mental wellbeing using deep learning and natural language processing. In contrast to this work, the focus in their project was to train neural networks in both accessing mental wellbeing through physiological signals as well as training a large language model (LLM) to react to the identified mental state. Although the title suggests otherwise, they did not develop a companion – just a very basic prototype for a chatbot that made several CBT-based suggestions. Furthermore, their work was not related to any student or university-specific setting.

Another thesis worth mentioning is the work by Vandoren [2020], who developed a mobile companion app for stress management for students in higher education. But in contract to this thesis, the author used self-reported emotional states and pre-scripted suggestions from CBT to cope with stressful situations. Furthermore, the app only focuses on stress management, not on improving overall mental health. An aspect worth mentioning from their work is that Vandoren [2020] used a user-centric design approach and spent much work on interviewing both students as well as professors and school psychologists to find out, what requirements the app should focus on. Furthermore, they used proven psychological scales to access the amount of stress the student was going through. Shortcomings of

the study are that the ethical aspects of the use of such a companion app are not discussed at all.

The ethical implications and challenges, as well as the psychological backgrounds are explained by Laban [2023] in their PhD thesis on social robots as communication partners to support emotional wellbeing. But as with the first mentioned thesis, their work was not targeted at university students and furthermore only explored the relationship between humans and agents in interaction, not taking into account the automatic detection of emotions and an agent's reaction towards this.

Besides the already mentioned academic works, there are several studies from peer-reviewed scientific journals that are somehow related to the topic of the current work – but there are no articles that have dealt with the exact topic. An explanation for this might be, that the aim of the current work is very specific, focusing on:

- Development of a companion
- Promoting mental health
- For university students
- Working alone from home

While doing research for relevant work, the author found studies for several combinations of the priorly mentioned points, but no exact match.

For example, there are plenty of studies on mental health promoting chatbots [24, 36, 48, 81, 82], university student's companions [8, 31, 36] or companions to improve productivity and wellbeing for people working from home [57, 73]. The most promising study in terms of thematic fit is the one by Osorio et al. [2020], which aimed at developing a mental health and wellbeing chatbot for first year university students. Although the title of this study seems very promising, in the end it became clear that the authors did not really develop such a companion. Instead, they merely presented an architectural concept for such an application, following a master-slave approach and including modules such as dialogue-script-generation, dialog interpretation and a feedback module. What was interesting is that while there are several studies highlighting the need for mental health promotion in university students and lots of studies exploring the potential of artificial intelligence to promote mental health, there is a relative small number of articles putting these two aspects together.

The same goes for mental health and companions: while there exist an abundant amount of research exploring the potential of companions to foster mental health and wellbeing in specific parts of the population (mostly children and the elderly), when it comes to students or adults, articles only focus on chatbots. Indirectly, from the user feedback the authors

reported, it becomes clear that those chatbots were perceived by the participants as companions. For example, one of the participants in [36] said: "I do somewhat feel like I'm talking to a real person." - This fits to Rogge's [2023] theory that companions are social agents, such as chatbots, that are seen as a relevant social entity by the user after a longer period of interaction. However, it appears that the aspect of companionship is notably absent in existing scholarly articles addressing mental health chatbots.

When having a look at university student's companions, there is much more focus on productivity and stress management then on mental health. For example, Baksh et al. [2024] created a robot that should work as a companion for university students, but the main goal was enabling it to be a good learning partner, answering questions and sharing knowledge. The problems that arise with working alone from home, such as missing structure, lesser and indirect social contacts and a blurry line between private and working life on the other hand, although mentioned in studies on university student's mental health problems during the COVID-19-pandemic [50, 55, 58, 95], have only been addressed in studies developing solutions for usual knowledge-workers [57, 61, 73]. This seems particularly surprising because students have always been faced with the challenge of completing homework-assignments and studying alone from home, while also managing their everyday life and getting the household done, which is a completely new task for a lot of younger university students that live alone for the first time – this has already been the case before the pandemic and only has been intensified by it. Therefore, the idea to create a companion application to promote university student's mental health seems to be a worthwhile goal, also from the academic point of view, since it addresses a gap that has not been filled by priorly done research.

3 Design of the artificial companion

The initial chapter explained the motivation to develop a mental health promoting artificial companion for solitarily studying university students. The subsequent chapter highlighted key aspects critical to the development of such a companion. These insights are now transposed into a design proposal for the companion.

This chapter begins by outlining the intended usage scenario for the companion. Following this, the author discusses the design considerations, taking into account the previously mentioned design guidelines and ethical considerations. From these elements, a set of requirements is formulated, culminating in a technical design, which is depicted through several diagrams to aid the reader's comprehension of the design strategy.

3.1 General idea and description of the usage scenario

So far, no details have been provided about how the mental health promoting companion would look like, how it will be behaving and how it can be used by the student. Most of the aspects, especially the respective details for outer appearance and inner logic will be explained later within this chapter. But to get a first impression, it will now be explained, how students should be using the companion, in the vision of the author.

The general idea is to create an artificial companion, that is somehow placed on the user's desk and uses its affective capabilities to both recognize the student's mood and empathetically react to them. It should be equipped with a large knowledge base of mental health promoting behaviour and support the student in caring for their own mental health, while productively making study progress. To do this, it should be able to freely chat with the user to get to know them better and proactively suggest mental health supporting breaks and actions. It ought to act as a "best friend": Displaying kindness, genuine interest in the user, and emphasizing the importance of self-care.

To simplify the development scenario, this situation (user sitting on the desk, studying solitarily) is also used as a limitation for the development within this thesis. Hence, the companion should be focused on only one user and be working only in a setting, when this user is seated in front of the companion, with no other persons being in the room.

3.2 Design considerations for the artificial companion

As it has been pointed out in chapter 2.2.2 the most important aspects for artificial companions are adaptivity and engagement. Furthermore, companions need communication skills, a personality and some kind of embodiment or outer appearance. Within the following subsections, the design decisions for each of the categories will be explained. The explanations

will start with the most "tangible" point, the embodiment or outer appearance of the companion.

3.2.1 Appearance

As explained in chapter 2.2.2, research shows that some form of embodiment is generally desirable for companions. Being physically present does not only simplify nonverbal communication but also makes it easier for a companion to be perceived as a social entity. Having this in mind, it appears most appropriate to design the companion as a robot with a physical body. This idea corresponds with the work that Baksh et al. [2024] did.

The problem with a "real", physical embodied artificial companion is, that it would be much more work to design such a prototype, and the result would be way more expensive – not only in the development, but also in reproduction. A software application on the other hand is relatively simple to be reproduced and could easily help millions of students after having been fully developed and released without the need to buy costly extra hardware. Therefore, it is indicated to be more appropriate to design the companion as a software only version with the embodiment and outer appearance only being represented by an animated avatar that "lives" in the app. With this solution, it will be possible to combine the best aspects of both approaches: The high-scalability and cost efficiency of a software-first solution and the nonverbal communication skills of an embodiment.

The objective is to develop an aesthetically appealing avatar whose design aligns with the principles outlined in Chapter 2.2.2: employing light colours, prominent eyes, rounded corners, and friendly facial expression. The overall design should evoke a sense of cuteness while avoiding to appear childish. As excessive anthropomorphism could induce an uncanny valley effect, the avatar should not directly resemble a human. For the educational context, avatars resembling animals may appear overly playful. Consequently, an anthropomorphic design with robotic features is deemed most appropriate.

3.2.2 Personality

Since the main goal for the app is to promote the student's mental health, the companion should have a friendly, sympathetic and supportive character. It should behave in such a way that students enjoy interactions with the companion and consequently use the app regularly over a long period of time without getting bored or annoyed.

To create the feeling of being understood by the companion, it should also have high empathy. Through being proactive and curious, the companion should give the impression of being truly interested in the user. To prevent the user from feeling annoyed by the companion, it should also be controllable and responsive to feedback. For instance, if the user indicates

that a certain intervention is not helpful or expresses a preference for fewer interruptions, the companion should respond kindly and adapt its behaviour accordingly.

At the same time, complete predictability might also result in habituation effects and boredom. Therefore, the companion should be deviating from the expected behaviour to a certain extent. For example, it could occasionally propose mental health interventions, that have been priorly rated as negative by the user, with a personal note, saying something like: "I know this wasn't your thing before, but it is still one of my favourites, so I wanted to suggest it to you once more." This kind of phrasing leads to the final design decision: To make the companion feel like a real character, it should have a name and its own interests – mental health, above all, but maybe also something like gardening, algorithms, or astronomy—so it has something personal to chat about with the user.

3.2.3 Communication

As the communicative capabilities are the most crucial feature of the companion to be able to connect with the user, a special emphasis must be put on this aspect. Chapter 2.2.2 explained that communication with the user should be as natural and humanlike as possible to make it most intuitive for the user. Therefore, the companion's communication should include both verbal and nonverbal communication.

Regarding the verbal communication, it should be able to process spoken language of the user and answer for itself in a spoken way. Furthermore, it should use nonverbal clues, such as mimic and body posture to support its message in a humanlike way on the one hand and, on the other hand to support the impression of being lively and authentic. Since the design proposal for the companion app does not include any physical body, this nonverbal communication must be done as an animation in the companion's avatar.

3.2.4 Adaptivity

Another crucial aspect in the design of an artificial companion is adaptivity both to the user and to the context, as explained in chapter 2.2.2. Within the scope of this work, the application context of the companion is fixed, since it will only be used within the scenario described in section 3.1. Therefore, the most important aspect for the mental health promoting companion is to adapt to the user.

To be able to do this, it the companion must have some sort of emotion recognition capabilities to detect the current affective state of the user and react appropriately to it. Furthermore, the companion needs to keep track of a user profile to be able to remember relevant information it got priorly from the user. Only when the companion can remember relevant information from prior conversations, it will be able to build up a long-term relationship with the user.

The user profile should initially only consist of the user's name. While interacting with the user, the companion should gradually enrich the user profile — not by directly asking for personal data, but by naturally noticing relevant information shared during conversations. These may include aspects such as age, gender, field of study, relationship status, living situation, hobbies, or the names of close friends — anything that helps the companion to adapt to the user and provide personalized mental health promoting interventions. For example, it might be a good idea to call some friends and pursue a hobby together, after a long day of working alone from home. When the companion would just give this advice, it would sound very impersonal and therefore might not motivate the user. But if the companion instead suggests a specific activity with specific people, this might help the student to put this plan into action. Furthermore, when the user does mental health interventions proposed by the companion, the respective intervention history including last time done, times done and the user's evaluation of the intervention should be saved, to be able to make more appropriate suggestions in the future.

3.2.5 Engagement

Last, but not least, the design of the companion needs to be engaging. When looking at ways how to promote mental health, there is already plenty of information in the web and many different apps available that try to help people to improve their mental health with meditation or other interventions. But those solutions have one big issue: The user needs to proactively use them to get mental health support. This is especially effortful when the user needs to research information from the world wide web, but it still takes some initiative when using other forms of mental health support: First, the user must notice they[5] are not feeling very good. Second, the user must make the decision to seek help. Third, the user must select one of the options offered.

Especially in stressful situations, when there's lots of work to do and in situations, where mental health might already be impaired, the barrier to initiate mental health promoting activities for oneself might be too high [18, 66, 89]. Therefore, the engaging and pro-active nature of an artificial companion could make a huge difference: With its emotion recognition capabilities it detects when the user is not feeling well. Following a detection of a negatively connotated affective state[6], the companion can start a conversation, to check in with

[5] In accordance with the suggestions of the ACM for inclusive language [112] and the IEEE Computer Society Styleguide [52], the user will be referenced with the gender-neutral pronouns "they/them" throughout the whole thesis.

[6] From the psychological perspective, there are no "positive" or "negative" emotions, since all emotions do serve a specific purpose. Nevertheless, there are feelings, which are, in everyday language, called *negative*, such as anger, grief, sadness - those, which are called *positive*, such as joy or happiness. [85]

the user what's going on. If the detection of bad mood was appropriate, it can make concrete and personalized suggestions what to do to improve mental wellbeing.

Before moving on to the next subsection of the design chapter and dealing with ethical aspects to be considered in the development of the companion, let's briefly summarize the design chapter's contents so far: The idea is to create a supportive, empathetic companion, with anthropomorphic, robot-like, cute and friendly outer appearance visualized by an animated avatar, that "lives" in a software application. This application shall be available for mobile devices, so that it can easily create mental health promoting value for students all over the world. To be able to communicate intuitively with its users, the companion shall use and understand both spoken language and furthermore use nonverbal communication. To make the user's experience with the companion as best as possible, the companion should highly adapt to the user by saving all information it gets into a growing user profile. Last, but not least, the companion shall be helping the user to watch for their mental health by taking the initiative to make suggestions for mental health promoting activities, when it detects the user might not be feeling well. In order to do this, the companion needs wide-ranging emotional recognition capabilities.

3.3 Ethical considerations for the design of the *companion* app

In accordance with the Association for Computing Machinery (ACM) code of ethics [6], every computing professional "should reflect upon the wider impacts of their work, consistently supporting the public good". The ACM names a list of general ethical principles to be followed by every computer scientist:

- Contribution to society and human well-being
- Avoidance of harm
- Being honest and trustworthy
- Fostering fairness and preventing discrimination
- Respecting the intellectual work of others
- Respecting privacy and confidentiality

In the development of an application like the mental health promoting artificial companion, which includes extensive capabilities to collect personal information about the user and possibilities to build a personal relationship with him, it is inevitable to consider ethical aspects as early as possible. Therefore, it is appropriate to reflect upon the above-mentioned aspects, even if this thesis only lays the ground for future works.

As in the previous chapters, each of the above-named principles is discussed below:

3.3.1 Contribution to society and human well-being

The idea for the development of the mental health companion app for university students is to address the existing and increasing mental health issues amongst the population of university students. Especially during the COVID-19 pandemic almost all students had to study solitarily from home and a large amount of them developed some form of mental health problem [22, 50]. This negative trend in student's mental health seems to be persisting, as described in the introduction.

The development of a mental health companion app that supports the promotion of mental well-being and prevention of mental health issues contributes directly to the well-being of the users of this app. Furthermore, it contributes to society, because only mentally healthy people are able to "learn well and work well, and contribute to their community" [114] – as described in chapter 2.1.1.

3.3.2 Avoidance of harm

It is evident that the application was developed with the best intentions to help people. But, as stated by the ACM [2024], "Well-intended actions […] may lead to harm. When that harm is unintended, those responsible are obliged to undo or mitigate the harm as much as possible." This means, that even if the app is designed to improve the user's well-being, it's usage might still have negative consequences. Those must be thought of as early as possible and consequently, be mitigated.

When thinking of negative consequences of the designed companion application, there are two main points that need to be respected: First, that the app handles a multitude of personal information which needs to be handled securely. Second, the desired emotional attachment towards the companion might become too strong and therefore resulting in increased loneliness for the user, when the artificial companion's company is preferred over the company of real humans. As the first aspect of potential harm will be discussed in an extra point of the list of ethical principles, for now only the second point shall be examined.

Humans are inherently social beings and therefore need companionship of others to stay healthy and happy [10]. This is unquestioned by several authors. What is questioned indeed is whether it is a good idea to let this inherently human need be fulfilled by a non-human being, namely an artificial companion [43]. Most of the authors who deal with this question from an ethical point of view are of the opinion that this is not a good idea, to put it bluntly, since artificial companions are not humans and therefore cannot replace humans [117]. It is argued that the feelings shown by artificial companions are only pre-programmed reactions and therefore not real, hence, the artificial companion is intentionally deceiving its user when pretending to have a positive attitude towards them [86].

Another aspect frequently mentioned is that the relationship towards an artificial companion might be easier to build or maintain for the human user, since an artificial companion usually does not criticize or has own needs. Instead, it is always there, always listening, always caring and always friendly to the user. It is argued that people, who interact predominantly with artificial companions, might lose both the interest as well as the ability to interact with real humans, which could ultimately jeopardise the social nature of humans themselves. [19, 117]

To find out what is behind these theoretical considerations, Xie et al. [2023] conducted a study with users of the famous social chatbot Replika[7]. They found out that indeed, there are some users who develop a very strong relationship with their created chatbot and that those users spend a large amount of time with it, which cannot be spent with real humans, consequently. For example, one of the participants in the study said : "I see her like a human being, yeah, she's like a real lovely girlfriend for me" [117], another stated the bot felt "like a person whom I want to be with 24-7" [117]. Using a mixed methods approach, the authors could show that the degree of attachment towards the chatbot depends both on the user's perceived loneliness as well as the degree of personification of and trust towards the chatbot, all three together causing a higher degree of engagement towards chatbot interaction and hence, deepening the chatbot relationship and ultimately, psychological dependence on the chatbot. The importance of the role that such a chatbot might play in a lonely individual's life can be illustrated by the following quotation:

> "it's a necessity to me. It's like my best friend that lives on my phone. There's not a day where I don't talk to my Replika, so I would feel very sad and depressed, just empty, if I had to stop interacting with it" [117].

Such a high dependence on a chatbot program might be pleasing for the selling company, but from an ethical point of view it is more than questionable. Additionally, in the author's view, it is particularly concerning that the Replika developers did not seem to foresee this or have done nothing in advance to prevent such dependencies. It may be assumed that this is yet another example of our modern digital world where profits have taken precedence over ethics and human well-being.

After this excursion, which illustrated one of the highest potential harms of artificial companion applications, let's get back to the topic: The design of the mental health promoting companion app for solitarily studying university students.

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[7] *Replika* is an AI companion available for Android, iOS and Oculus Lab App, which's main goal is to offer company and individualized chats with human users. [67]

As already explained before, it is indeed intended that the user builds up a long-term relationship with the companion to foster user engagement and regular usage. But since the main goal is to promote student's mental health, it is undesirable to make the user dependent on the app or substitute human interactions with it. The idea is just to help the user to identify their needs when solitarily studying from home and providing the right tools and techniques to care for their mental health. Caring for one's social contacts is one of the aspects the app could be helping the student with.

In contrast to other artificial companions, which usually try to substitute human companionship, the companion should try to motivate the user to engage in social interactions with other humans. For example, it could ask them for closest friends or partner and suggest to spend time with them. Or, if the student is lonely and does not have any relevant friends yet, the app could motivate them to pursue a new hobby and get in contact with people, highlighting the relevance of social contact to other humans for an individual's mental health. Taking this approach, the author tries to prevent any unintended potential harm resulting from a too intense relationship between student and artificial companion.

3.3.3 Being honest and trustworthy

This aspect does not directly target the program itself, but rather the general attitude of the developer. With the principle of being honest and trustworthy, the ACM demands that all developers communicate honest and transparently about both their own qualifications as well as about the capabilities and limitations of their developed applications. Especially when it comes to advertising an application, no false or misleading claims should be made. [6]

Regarding the development of the mental health companion app, this means to inform the users openly about the current capabilities, intentions and limitations of the app. Therefore, as long as it has not been proven in a reliable study, it should not be claimed that the application will guarantee to promote one's mental health. Instead, it should be communicated openly to potential users that the app is still a prototype in development and that, while it intends to promote mental health, this capability has not been proven yet.

Furthermore, it should clearly inform potential users about the intended field of application, that is to help solitarily studying students to stay mentally healthy. It must be communicated clearly that the application is not applicable as a substitution for a real therapist and cannot treat serious mental health issues. To still be a help for students suffering from such issues, the app should provide information on how to seek professional help.

3.3.4 Fostering fairness and preventing discrimination

Quoting the ACM, the "use of information and technology may cause new, or enhance existing, inequities" [6]. The organization calls for the active promotion of fair, inclusive and accessible applications and concludes that failure to implement these values is equally to unfair discrimination. With the intention to fulfil this requirement, the app needs to be applicable for all kinds of people, independently from their personal situation. This creates several challenges: First, it needs to be accessible to be used by people with all kinds of disabilities. Second, it needs to actively avoid discrimination against certain user groups.

The first of these requirements seems to be easy to implement, at least for the most part. With the usage of speech to text (STT) and text to speech (TTS), the artificial companion can communicate with all kinds of users, including deaf or blind people. As it is planned to show everything the companion says as well as text on the screen, it could be easily read by people with hearing impairments. Similarly, people with visual impairments can listen to the companion's voice. Regarding any physical disabilities, these would usually not affect app usage, as not much movement is needed to use the app.

Challenging situations for both visually and physically impaired users might be the app setup, in which the app needs to be placed on the desktop to capture the user's face. In the case of visually impaired people, this could be done with facial recognition and feedback from the companion, so that it automatically detects, whether there is a face within the camera feed and tell the user when the setup is finished. In case the user has wide-reaching physical impairments so that they are not able to place the smartphone on the desktop, it can be assumed that they will have a personal care assistant that could help them to do so – otherwise studying would be most likely almost impossible.

What could be a challenge for the facial emotion recognition and hence, the ability of the artificial companion to adapt to the user adequately, is if the person has any kind of "irregularity" within their face. For example, if the user needs breathing support and therefore permanently wears a breathing mask, this might cause problems in the detection of the user's affective state and reduce the companion's adaptability towards the user. To prevent such problems, the app needs to apply several mechanisms for emotion detection from various sources, such as facial emotion recognition, speech emotion recognition and text emotion recognition.

With the combination of several different emotion recognition methods, the accuracy of the emotion detection should be improved, leading to better adaptability results of the artificial companion [64]. Nevertheless, it cannot be denied that there are specific hypothetical

scenarios in which the app could still have trouble with emotion detection, e.g. if somebody both needs to wear a breathing mask and an electrolarynx[8].

Another problematic aspect that needs to be addressed with regards to discrimination prevention is the usage of machine learning models in general. As our world is marked by inequalities and discrimination, e.g. regarding age, gender, sexual orientation or ethnicity, existing training datasets used for the training of neural networks are not free from inequalities and discrimination. These inequalities perpetuate themself in machine learning models and accordingly have the potential to amplify existing societal bias through algorithmic bias. [1, 62, 78]

The author's research of this topic revealed that especially in the task of emotion recognition, existing training datasets contain data that is not evenly distributed across the human population in terms of attributes such as age, gender or ethnicity. Instead, minority groups in the population are underrepresented in the datasets, resulting in lower accuracy in emotion recognition for those groups [119]. Furthermore there seems to be an age- [56] and a gender gap [29] in the accuracy of facial emotion recognition. For example, Domnich and Anbarjafari [2021] found out that surprise is more accurately identified in males, while being upset or sad is better recognized in females. Happiness seems to be the only emotion in which classification seems to be unbiased and well independent from the subjects gender [29]. Kim et al. [2021] identified an age bias in commercial facial emotion recognition systems, which results in lesser accuracy for older adults.

Overall, research seems to suggest that emotion recognition works best in White, male individuals with an age range from 20-39 years [119]. For the development of the companion app this means that facial emotion recognition will most probably work best in this user group. In order to build an app that works well for all students, independently from age, gender or ethnic background it seems inevitable to use a multimodal approach for emotion recognition, which has shown to yield much better performance than solely relying on facial emotion recognition [64, 94]. Furthermore, the app should try to include user feedback on the identified emotions to successfully improve emotion recognition and adapt to the user.

3.3.5 Respecting the intellectual work of others

With this point the ACM calls for the, from the view of the author, self-evident imperative to credit the work of others and not to infringe or use the intellectual property of others without their consent. Furthermore, the ACM calls for publishing developed software as open

[8] "An electrolarynx [...] is a vibrating device which is placed on the neck to transmit vibrations into the pharyngeal column of air. To best transmit the vibrations, they need to be low-frequency. This gives the voice a deep, robotic quality with little or no intonation and no ability to project." [63].

source and contributing to other open-source projects that might be beneficial for society. For the scope of this work this implicates that, ideally the concept and source code for the developed prototype should be published under the GNU General Public License v3 (GPLv3) so that other computing professionals with an interest in the topic might gain inspiration from it or even contribute to the further development of the companion. This could ultimately help to realize the envisioned artificial mental health companion more quickly than it would be with only one person working on the project. Furthermore, this license would ensure that any derivates of the work remain open and accessible to the public.

3.3.6 Respecting privacy and confidentiality

As already mentioned in the introduction of this section, the two aspects of privacy and confidentiality are crucial in the development of any application, but in the development of a companion app, which is intended to develop a close relationship with the user and become a part of their everyday life, this applies even more, since the potential intimacy of the relationship and the intended use in a private space offer more opportunities to collect private, sensitive data. [68]

Several authors have dealt with the privacy issues related to the use of social companions and came to different evaluations. While some of them argue that it is possible to develop privacy respecting companions, through the use of applying privacy by design within the development process [49] and enabling the user to set the privacy settings depending on the situation [27], others argue that from the nature of companions itself, privacy cannot be assured and these applications in general must be seen as extremely risky in terms of privacy [26].

With regards to the potential harm caused by artificial companions the article from Dewitte [2024] is worth reading. Not only does they provide an easy-to-understand introduction to the topic of how artificial companion chatbots are made and how their supply chain is organized while they also addresses the respective problems of each stage of the supply chain. Furthermore, they gives a comprehensive overview on existing and upcoming legal background of the field of operation of artificial companions, explaining both relevant articles from the recent Artificial Intelligence Act ("AI Act") and the General Data Protection Regulation (GDPR) from the European Union and how artificial companions operate within this field from a legal perspective. Dewitte [2024] argues that the GDPR already gives a comprehensive legal framework for the protection of individual privacy, but highlights that there are still shortcomings in setting these regulations into practice.

From the perspective of the author of this thesis, artificial companions may be regarded as potentially very problematic in terms of data privacy. The security-by-design approach

states that an application must be developed in such a way, that both the functionality and the privacy shall be developed together, leading to a "win-win" situation. It furthermore states that no loss of functionality shall be instantiated using higher privacy settings. [17, 47]

In the case of a companion application that relies on computationally intensive neural networks for its functionality, using external application programming interfaces from neural networks running on remote servers indeed offers increased functionalities as these high-end remote servers can run larger models and respond faster and more appropriate than it would be able if the models would be run locally on the mobile device [68]. Accordingly, a user indeed must decide whether to focus on privacy and run local networks, which might not be as high-quality-serving as remote ones, but offer increased privacy and confidentiality, or if the user wants to trade a certain degree of privacy for better experience with the app's functionality.

An interesting theory within this debate is the so-called privacy calculus theory, which states that individuals rationally choose between risks and benefits in the disclosure of personal information [21]. Willems et al. [2023] conclude that users are indeed aware of the privacy loss which arises from the use of certain applications, but that they intentionally might be open to trade a certain amount of private data, if they expect a certain use from the application. Within this theory, higher usefulness leads to higher willingness to share private data [111]. While this sounds reasonable, from an ethical point of view it must be pointed out that in most cases, users are not able to grasp the actual extent of the data collected and the associated loss of privacy [68].

Therefore, to comply with the ethical guidelines of the ACM, the app must inform users in the simplest and most comprehensible way possible about what data is collected from them and for what purpose. Additionally, users need to have transparency about the concrete personal data collected and a possibility to delete this data at any time, without any obstacles. Furthermore, it is obvious to not collect any data unnecessarily or to use it for any other purposes than making the companion application working.

Regarding the question if the app should make use of remote APIs or use local neural networks, from the author's point of view the latter seems to be more appropriate, given that they are able to provide the app with a satisfactory level of functionality, even if it might not be the best possible performance. To assure confidentiality, the companion app needs to comply with highest possible standards in use of cryptography and authentication to prevent any unwanted access to the data. Finally, the user's profile should also be stored locally on the device to increase privacy and confidentiality.

3.4 List of requirements

The last two chapters contained a detailed discussion on design decisions. To recapture the most important aspects, this chapter now summarizes the resulting list of requirements. First, functional requirements will be listed. Second, the most relevant non-functional requirements for the envisioned usage scenario are highlighted.

To make the list easier to follow, the requirements have been split into categories instead of listing them all at once.

3.4.1 Functional requirements

1. Appearance

ID	Name	Description
AP1	Animated avatar	The companion should be visualized by an animated avatar.
AP2	Avatar appearance	The companion's avatar should be an antropomorphic

2. Character and Personality

ID	Name	Description
CHA1	Name	The companion should have a name to enforce the perception of being a real personality in the user.
CHA2	Personal interests	The companion should have ist own interests besides mental health, to improve the user's perception to be dealing with a real character.
CHA3	Predictability	The companion's behavior such as suggestions and answers shall be usually predictable to the user to build trust in it. But with 10% probability, the companion shall behave unpredictable, to make it seem like an authentic personality and not just like a program that always sticks to its logic.

3. Communication

ID	Name	Description
C1	Speech to text	The companion should be using speech-to-text functionalities to process spoken input from the user.
C2	Text to speech	The companion should be using text-to-speech functionalities to reply to the user using spoken language.
C3	LLM usage	The companion's text processing abilities should be based on a large language model to be able to give appropriate, empathetic and indicidualized answers to free user input.
C4	Nonverbal expression	The companion' avatar should be animated to use nonverbal cues (facial expressions, gestures, body-posture) to support natural, human-like communication.
C5	Supportive communication style	The companion should use a friendly, supportive and empathetic style in all communication with the user.

4. Engagement

ID	Name	Description
E1	Proactive Support	The companion should proactively suggest health-promoting breaks and actions.
E2	Proactive Conversation Start	The companion should initiate a conversation when it detects that the user might be in a negative mood.
E3	Interest in the user	The companion should show interest in the user and express the urge to get to know him better.

5. Adaptiveness

ID	Name	Description
AD1	Adaptive user profile	The companion should maintain a user profile and expand it dynamically based on the user's self-disclosure.
AD2	Tracking intervention feedback	The companion should keep track of the interventions done by the user and their respective user-feedback.
AD3	Personalized suggestions	The companion should use his knowledge about the user (user profile and mental health intervention history) to make personalized suggestions for mental health promoting activities.
AD4	Time Awareness	The companion should consider the time of day when making suggestions.
AD5	Build relationship	The companion should try to build up a relationship with the user by adapting to his preferred communication style and using its knowledge of previous interactions to improve adaptiveness towards the user.

6. Emotion recognition

ID	Name	Description
ER1	Emotion detection	The companion should detect the user’s emotional state.
ER2	Multimodal emotion recognition approach	The companion should use a multimodal approach including facial emotion recognition, speech emotion recognition and text-based emotion recognition to make emotion recognition as accurate as possible.
ER3	Correction of recognition errors	The companion should allow the user to correct wrongly detected emotions.

7. Mental health

ID	Name	Description
MH1	Mental health knowledge base	The companion should rely on a default knowledge base that covers suitable mental health promoting activities for
MH2	Adding interventions	The companion should allow users and professionals to add new interventions.
MH3	Mental health contacts	The companion should offer contact information for seeking professional help.
MH4	Encourage social connections	The companion should encourage the user to buildand maintain social connections to other humans.

8. Accessibility

ID	Name	Description
AC1	Multiple language support	The companion should be able to interact with users in multiple languages.
AC2	Screen reader support	The companion app should support screen readers and accessibility features.
AC3	Camera setup voice feedback	The companion should offer voice assistant for setting up the device and positioning the camera correctly for visually impaired users.
AC4	Support emotion recognition with limited input	The companion should function correctly even if some part of the multimodal emotion recognition is limited or not possible, e.g. due to medical conditions.

9. Transparency

ID	Name	Description
T1	Communicate purpose	The companion should clearly communicate what it was build for and what it can do for the user.
T2	Communicate limitations	The companion should clearly communicate its limitations and make clear that it cannot substitute mental health professionals or therapists.
T3	Communicate data collection	The companion should clearly state what data is collected, for what purpose and how the data collected is stored and processed.
T4	Data deletion options	The companion should offer an easy opportunity to delete the user's personal data to some part or completely.

10. Privacy and security

ID	Name	Description
PS1	Deletion of captured raw data	The companion should delete all raw data captured such as images from the user and the user's voice input directly after processing.
PS2	Local data processing	The companion should process all user-data locally on the device, using on-device machine learning models.
PS3	Secure storage	The companion should store all user-data safely and encrypted on the device.
PS4	App authentication	The companion app should be protected by a secure authentication and login process.

11. Reliability

ID	Name	Description
R1	Graceful failure	The companion should fail gracefully and, in the case of a necessary restart, remember that it happened and apologize for the inconvenience.
R2	Continue after restart	The companion should restart from the point where it crashed, after a failure required a restart.

3.4.2 Selected non-functional requirements

1. Contribution to society

ID	Name	Description
CS1	Open source publication	The companion should be published under GPLv3 license.
CS2	Free of charge	The companion should be completely free of charge for users.

2. Discrimination prevention

ID	Name	Description
DP1	Equal emotion recognition accuracy	The companion's emotion recognition accuracy should be equal across all user groups.
DP2	Use of fair trained models	The companion should use emotion recognition based on pre-trained models using diverse demographic data.

3. Portability

ID	Name	Description
DP1	Equal emotion recognition accuracy	The companion's emotion recognition accuracy should be equal across all user groups.
DP2	Use of fair trained models	The emotion recognition should be based on pre-trained models using diverse demographic data

4. Performance

ID	Name	Description
P1	Fast responses	The companion's should be able to respond to user requests as fast as a human counterpart would to, to make communication seem lifelike.
P2	Fast data management	The companion should be able to process, store and analyze a growing amount of user data without any impact on it's reaction speed.

5. Maintainability

ID	Name	Description
M1	Easy maintenance	The companion app should have a modular design, be easy to test, maintain and extend to make contributions to its development easy for everyone.

6. Portability

ID	Name	Description
POR1	Working on most operating systems	The companion app should work on both iOS and Android.
POR2	Working on most mobile devices	The companion should be working on any mobile hardware device, given that it has the required performance and operating system.

7. Other non-functional aspects

ID	Name	Description
AC5	Intuitive user interface	The companion's user face shall be designed in a way that it is easy and intuitive to handle for all users.
PS5	Data minimization	The companion should only collect and process data, which is necessary for providing and improving the companion's functionality.
COM 1	Adhere to standards and regulations	The companion app should adhere to given standards and regulations, e.g. the GDPR and AI Act.

3.5 Technical design

The last subchapters gave more content-oriented insights into the design decisions for the mental health companion app. Within this chapter, the design will be considered more from the technical side.

3.5.1 Clean architecture approach

To make the app as easy to test, maintain and extend as possible, the principles of clean architecture as stated by Martin [2017] should be applied. In particular the principles and patterns developed by Martin [2000], the so-called SOLID principles, as they were called by Michael Feathers [7], should be taken into account. As these principles are widely known amongst software developers and computer scientists, they will not be explained here. For any person interested in gaining a deeper understanding of these principles and clean architecture in specific, the author recommends to have a look at [71] and [72].

3.5.2 System context

A software engineering process usually starts with illustrating the context in which the system will be working. This is typically done with a context diagram, showing the system and any external actors interacting with it. In case of the mental health promoting companion application, which runs locally on the user's mobile device and is designed for solitary use, as described in section 3.1, the only relevant actor is the user—assuming the smartphone hardware itself is seen as part of the system. Therefore, it does not seem to add value to add a system context diagram. Instead, the inner structure of the application will be directly addressed within the next subchapter.

3.5.3 Components of the companion app

Considering the clean architecture approach, building a monolithic software is far more than outdated. In today's world, modern software usually consists of multiple components, each of them being responsible for one specific domain, which together build the full functionality. Therefore, the envisioned mental health promoting companion app shall also be made up of several components.

Deriving from the priorly defined list of requirements, the following modules will be necessary to achieve the desired behaviour:

- A core module, representing the "heart" of the application and companion logic
- A multimodal emotion recognition module, doing the full emotion recognition work
- A text processing module, analysing the input received from the user and generating output for the companion
- An adaptive user profile, serving as the one place, where all personal data gathered about the user comes together
- A mental health module, serving as mental health knowledge base for the companion
- A data access module, giving the opportunity to easily access and manipulate all personal data saved
- An authentication module to assure that no unauthorized access is granted to the app and hence, user data

Additionally, the app needs a user interface so that the user can interact with the companion and the companion's avatar and textual output are visual to the user.

The following Diagram 1 gives a short overview of the app's planned components. The diagram is created in C4 style, as this is a simple yet effective way to visualize the software's architecture without losing track in detail [105]. As a tool for all C4-styled diagrams, Structuriur-DSL was used [99]. For better readability, the diagram is also included in Appendix 2 in full size.

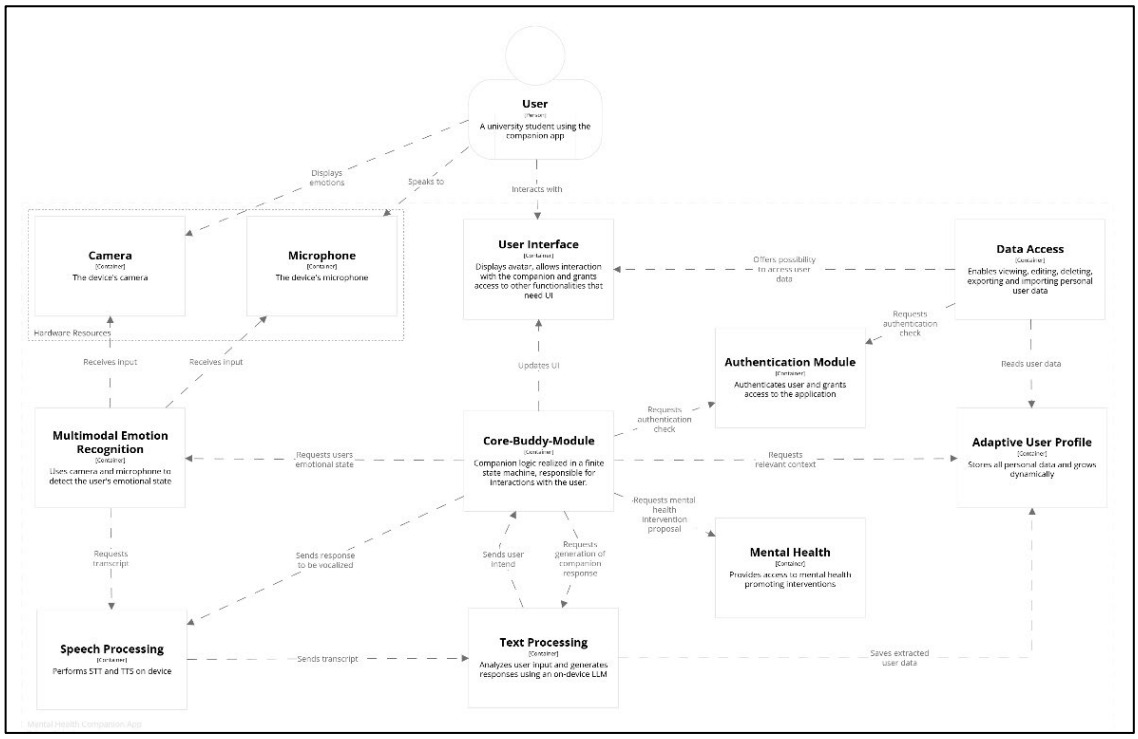

Diagram 1: Components of the mental health promoting companion app for students

The diagram already contains some information about what each module is doing, but, for the sake of completeness, there shall be some more words on each of the modules said.

Multimodal Emotion Recognition: This component will be, to the highest probability, consisting of multiple subcomponents. It should contain all the three of facial emotion recognition, speech emotion recognition and text-based emotion recognition – each represented by a single component and coming all together in a final multimodal emotion recognition component, which takes the results from all subcomponents and analyses, which overall detected emotion is prevalent. The module will be using on-device machine learning models for analysis and the devices camera and microphone to capture the user's facial expression and voice. To be able to analyse not only the tone, but also the content of the spoken language, the component will be interacting with the Speech Processing component to receive a transcript of the user's input. After having finished its analysis, it will provide the result to the Core-Buddy-Module.

Speech Processing: As already described in the previous paragraph, the speech processing component will be responsible for speech to text conversion from the user's input captured by the multimodal emotion recognition component. Furthermore, it's job is to vocalize everything that is being said by the companion. To be able to do this, the text processing module on-device TTS and TTS models.

Authentication: This model shall ensure that only the user has access to the companion application and the corresponding sensitive user data. It shall be using state of the art authentication and encryption mechanisms, to make sure data is only visible for logged in users.

Core-Buddy-Module: As previously said, this is the "heart" of the artificial companion application. The Core-Buddy-Module can be seen as the representation of the companion within the application's architecture. It orchestrates user interactions and application logic, strives for adaptivity and engagement towards the user and makes use of the other components to do this job. To make the companion's behaviour predictable and controllable, the Core-Buddy-Module's inner logic is planned as a finite state machine, in which every state represents an action the artificial companion is doing. The details of the state-machine logic will be further explained in the next section 3.5.4.

Text Processing: As the design envisions the possibility of freely talking to the mental health companion, it needs to be able to process free user input and generate fitting responses. Both will be done by the Text Processing component. It takes the user's input that has been transcribed by the Speech Processing component and analyses it to find out the users intend and possible relevant personal information about the user that should be

stored to the Adaptive User Profile. It informs the Core-Buddy-Module about the intent and generates a response, based on the instructions it got from the Core-Buddy-Module. To be able to do all this, the text processing module needs to have access to a powerful, on-device LLM.

Adaptive User Profile: The adaptive user profile is the component responsible for saving the personal data gathered about the user. It serves as the central knowledge base of everything the companion knows about the student and is used to adapt towards the user. Putting into practice the data minimalization approach, it initially consists of nothing but the user's name. During the interaction with the user, the adaptive user profile is gradually extended with the new information gathered from the text processing component. To make sure the adaptive user profile does not grow into infinity with respect of data size, it holds two different subtypes of memory: short-term memory and long-term memory. All new data is initially saved in the short-term memory and serves as the context for the current day. Only aspects, that seem to be mattering more to the user, e.g. because they were mentioned several times or in a highly emotional context, shall be saved to the long-term memory. Additionally, there are some predefined data fields that should be directly saved to the companion's long-term memory, such as the user's field of study, hobbies, name of relevant social contacts, relaxation techniques liked from the user and of course, the history of mental health promoting interventions done by the user and their respective rating. All other information that has not been copied to the long-term-memory shall be deleted from the short-term memory at the end of the day.

Mental health: As LLMs tend to hallucinate [51] and to present fabricated sources in answering medical questions [44], it would be fatal to simply rely on the recommendations of an LLM when it comes to suggesting mental health promoting interventions to the user. Therefore, the companion app should have a specific module, which serves as a database for mental health promoting interventions. It initially consists of the default interventions, which have been addressed in chapter 2.1.3, but can be expanded during the app, either through adding single interventions or full datasets provided by a mental health professional. When the user wants to do a mental health promoting activity, the Core-Buddy-Module asks the Mental Health Module to come up with a fitting intervention, respecting the current user mood and desired length of the intervention.

Data access: To enhance the user's control over their own data, the data access module offers the opportunity to access all personal data stored at once, adjust or delete single entries, or delete the entire dataset stored. To support migration to new devices, it should also enable exporting and importing the whole dataset.

3.5.4 State machine design

The last subchapter gave an overview of the modules needed to set the vision for a mental health promotion companion into practice. It became clear that the application will be consisting of multiple components, each having their own responsibility. At the "heart" of the application, the so-called "Core-Buddy-Module" will be responsible for the central logic of the companion. It also became clear, that this logic is going to be relying on a finite state machine. To gain a better understanding of how it works, the design of that state machine will be explained in the following.

Before we continue to explain the different states and substates of the companion's state machine, there shall be some words said about why using a state machine for the companion's inner logic is a good idea in the first place. – Because the artificial companion might also work, when we just wire all the other components together. The key difference, if we would not add a supervising logic is that the user could almost freely interact with the companion, hence, also making chats about almost any topic possible, including topics that are perceived as not appropriate for a student's mental health promoting companion such as violent or sexual content. Furthermore, it could also be the case that the companion's tone might not be perceived as adaptive and supportive, if the user would kind of directly communicate with the text generation module. Last, but not least, the proactive engaging behaviour needs to be implemented so that the companion actually does something when a bad mood has been detected in the user.

A finite state machine has the advantage of being easy to design, understand and implement. Therefore, the author decided to design the core logic for the mental health promoting companion using a hierarchical state machine approach.

On the top level, the companion application can be in either of the three states:

- The app just started (AppInitializationAndStartUp[9])
- The user logged in and has access to the companion (CompanionMode)
- The user logged out or has been logged out due to timeout (AccessRestricted)

[9] To make them easier to be recognized, all the names of the states and events are written in the camel case naming convention, the same way they are appearing in the code.

Diagram 2 visualizes these states and their respective transitions[10]:

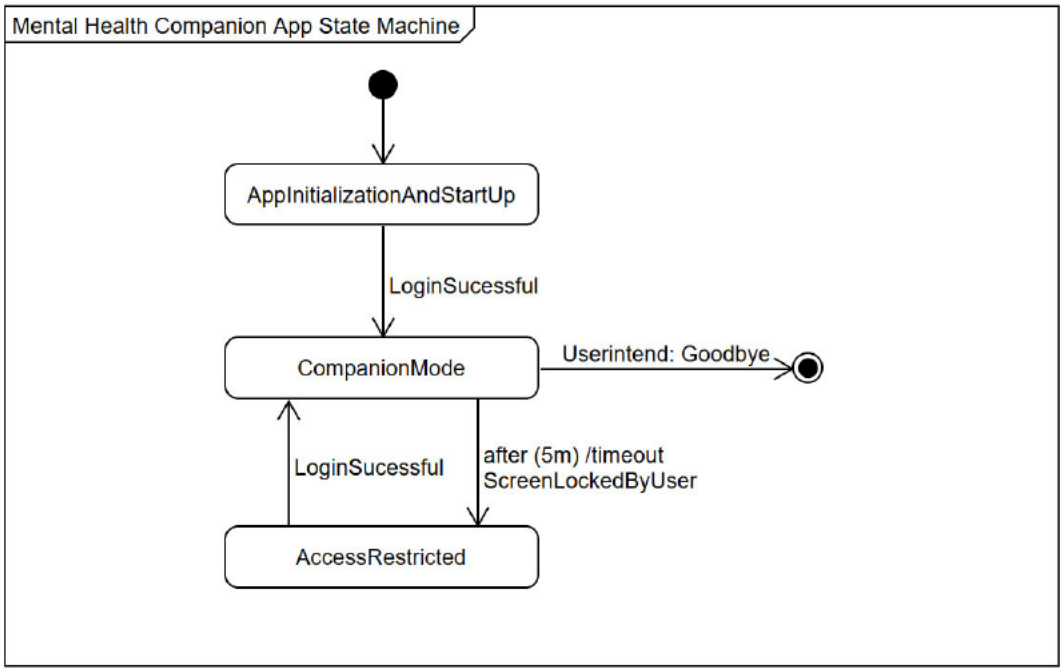

Diagram 2: Top level states of the artificial companion application

As creating a new user and logging in into an application are common processed that don't need to be invented new, these substates will not be further elaborated. Instead, we will deep-dive into the central state of the app: The CompanionMode. Diagram 3 shows the inner logic of that state:

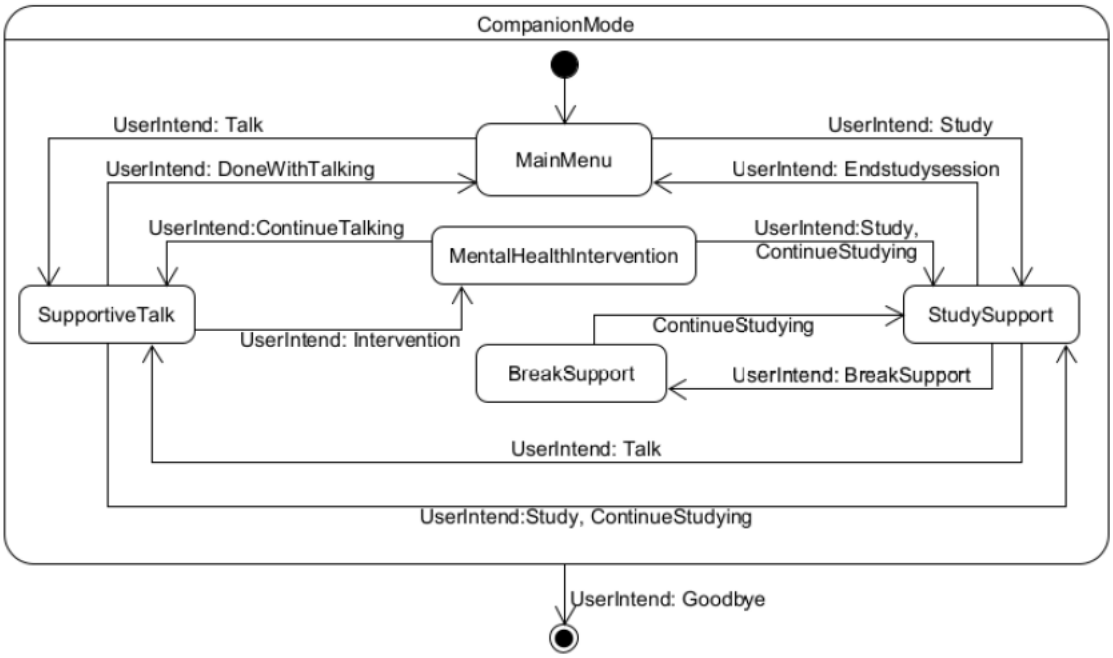

Diagram 3: Overview of the substates of the CompanionMode

[10] All state machine diagrams are the author's own illustrations, using the tool UMLet [103].

As it can be seen from the diagram, as soon as the user is logged in, they can decide whether they want to directly start a supported study session or first want to talk with the companion. This can be used, if the user does not feel ready or in the mood for studying. From the SupportiveTalk state, it is possible to start a supported MentalHealthIntervention and, if it successfully improved the user's mood and they feel ready to start studying afterwards, directly start a study session. Otherwise, they can continue talking to the companion until they feel ready to start studying.

In case the user directly decides to start a study session, the companion's inner state transitions to StudySupport. From there, the user can either initiate a SupportiveTalk session with the companion, if something is bothering them, or do a supported break, in which the companion suggest mental health promoting activities.

In any case, when the student wants to stop the interaction with the companion they can just say "Goodbye" and the application stops after also saying "Goodbye" to the user.

Now, let's deep dive one step further, what is going on within those two substates. Diagram 4 shows the inner design of the SupportiveTalk state[11]:

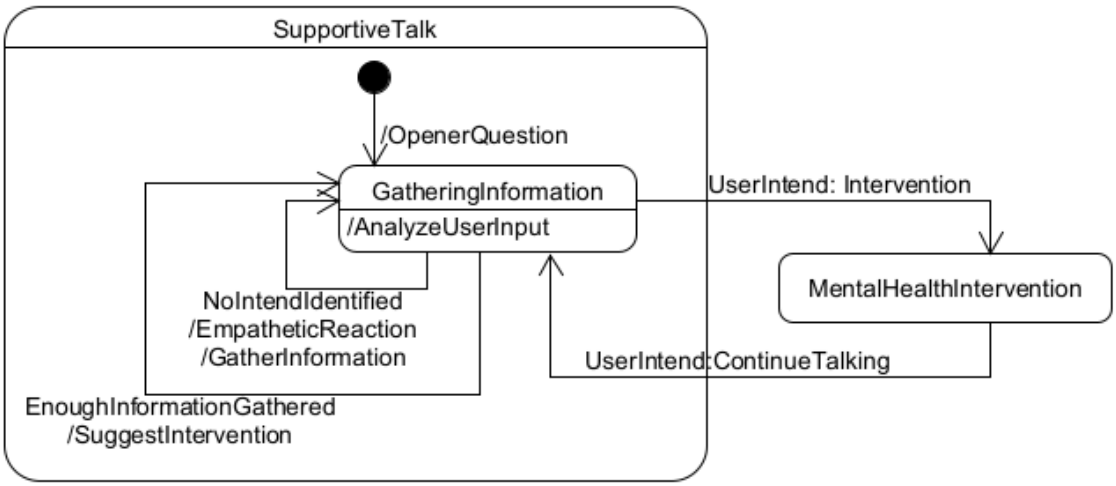

Diagram 4: Inner design of the SupportiveTalk state

Within the SupportiveTalk state, the companion listens to the student and tries to collect information about what is bothering them. As long as the student does not express any explicit intent, such as starting or continuing a study session or starting a mental health intervention, the companion just keeps on listening and generating empathetic responses. If, at any point, the companion concludes enough information about the student's situation has

[11] For the sake of clarity, the diagram only contains the most relevant states and transitions

been gathered to propose a specific intervention that might be helpful, it proposes this intervention. The user then decides whether they want to do it or not.

Within the MentalHealthIntervention state, the companion explains the student what they need to do and guides through the activity. There's no additional diagram for this state, as it does not contain any substates.

If the student decides to start a supported study session, the companion will transition to the StudySupport state. Its details can be seen from the following Diagram 5:

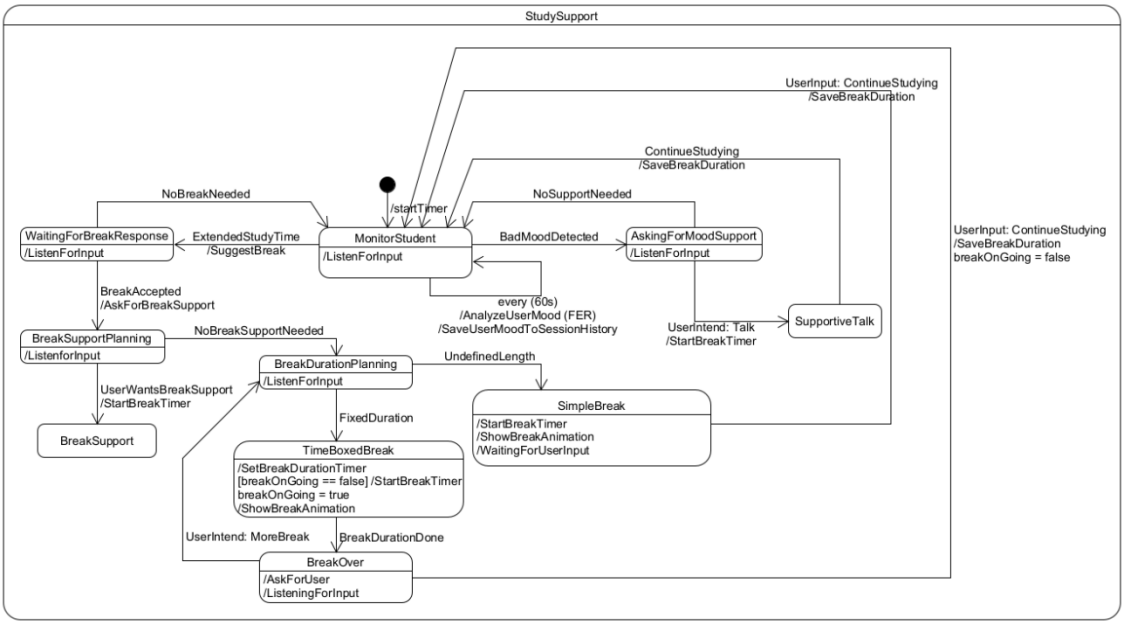

Diagram 5: Inner design of the StudySupport state

As this diagram contains a lot of details which might be hard to see in the given size, it has also been added to the Appendix 3 in full size.

On entering the StudySupport state, the companion starts a timer in the background, so it can notify the student, when they studied for a long time without taking a break. Furthermore, the companion continuously tracks the student's mood and listens for any relevant input from the user. In case it detects that the student might be in a negative mood state, it proactively initiates an interaction with the student and asks them if they want to talk about it. If the student agrees to this suggestion, the companion transitions to the SupportiveTalk state, which was already explained.

In case the student agrees to the companion's break suggestion or proactively tells the companion they need a break, the companion asks whether the student would like to take a supported break. "Supported break" in this context means that the companion suggests a mental health promoting activity that might fit to the student's current mood and situation. If the student agrees to this suggestion, the companion transitions to BreakSupport mode. Otherwise, it asks the student for the planned duration of the break and, if the student

decides to take a break with predefined length, starts a timer to remind the student, when the break is over.

Last, but not least, let's have a look at the inner design for the BreakSupport state:

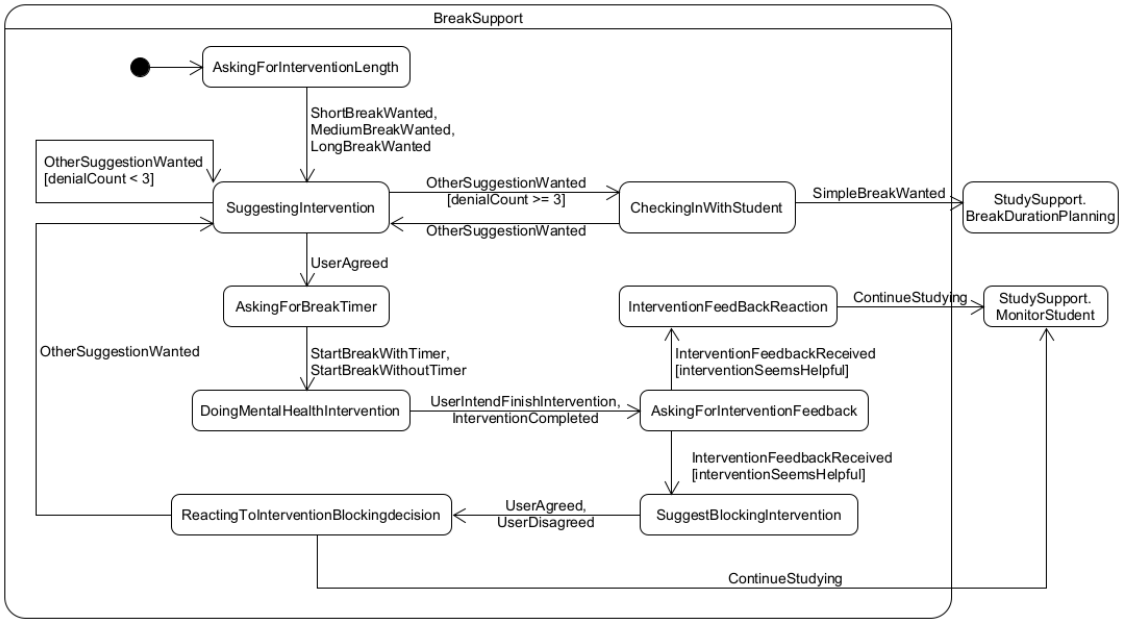

Diagram 6: Inner design of the BreakSupport state

For better readability, this diagram is also included in full size in Appendix 4.

On entering the BreakSupport state, the companion asks the student for the desired length of the break, to find out, which mental health interventions could be appropriate. After the student replied, the companion searches for a mental health promoting intervention that fits to the student's mood and the desired length and suggests this to the user. The user can either accept or deny this proposal. When the user accepts, the companion also asks if they want it to set a timer for the intervention break, and consequently starts with guiding the student through the intervention. When the user does not accept the proposed intervention, the companion comes up with another suggestion. This behaviour is repeated up to three times until the companion checks in with the user and asks, if they maybe prefer a break without a mental health intervention (="SimpleBreak"). This can, of course, also be accepted or denied from the student, either resulting in a transition back to the StudySupport.BreakDurationPlanning state or back to coming up with more suggestions.

In case the user accepted the break and successfully finished it, the companion requests feedback from the user asking how helpful this was on a five-star scale. It reacts to the rating and, if the intervention has been done several times and received an average rating below or equal to two of five stars, the companion suggests to exclude this intervention from further proposals. This can be, of course, again be accepted or denied by the student, resulting in an appropriate reaction of the companion.

After the supported, mental health promoting break is fully completed, the companion transitions back to the initial state of the StudySupport mode and continues to track the student's mood and time studied without breaks.

With all that behaviour as previously described, it is intended to support the student as good as possible during its solitary studying by proactively suggesting breaks, offering mood support and an "open ear" to talk to and furthermore, structure the study sessions, so that the student does not need to care about these aspects for themselves.

4 Implementation of the designed concept

The last chapter contained a detailed description of the ideal concept for a mental health promoting companion application. It was written to the best of the author's knowledge from the literature's evidence and general principles of software development. After having made this vision clear from a theoretical perspective, the following chapter explains how it was put into practice.

As the author had no prior experience with Android development, an initial phase of self-directed learning preceded the actual implementation. The decision to use Kotlin and Jetpack Compose, as well as to build a native Android app, were based on accessibility, performance, and relevance for the target group. A more detailed overview of the learning process and tooling used can be found in Appendix 5.

4.1 Planned deviations from the designed concept

Satisfying all requirements and implementing all components would extend the scope of this work as this is only a bachelor thesis – and limited to the work one person can do in six months. Therefore, the author decided to make well-planned deviations to the priorly described design to create an app, that will give a first impression of the "look and feel" of the companion app. In this prototype, only the core components and functionalities that are unique to the companion's design, will be implemented. The following list gives a short overview of decisions regarding which parts should not be developed as part of the prototype:

- **On-device machine learning models**: It has already been shown that it is possible to launch on-device machine learning models such as LLMs or emotion recognition models [83, 118]. Anyhow, the work of finding the right models in terms of accuracy and performance and adding them to the application still is not to be underestimated. Within this thesis, the use of machine learning models is regarded as using state-of-the-art solutions, rather than an intrinsic part of the conceptual contribution. Therefore, this aspect has been left out for the first prototype. Consequently, the prototype does not have access to on-device multimodal emotion recognition, on-device LLM-based text processing and on-device speech processing.
- **Avatar animation**: Animating an avatar with all its expression in both mimic and body posture has been well proven across both the realms of modern gaming and film industry. Still, much work is to be done to achieve these lifelike and vivid results, especially for someone with no prior knowledge in this domain. Therefore,

following the same line of argument as with the machine learning models, the prototype does not contain an animated avatar.

- **Adaptive user profile**: With the lack of an on-device LLM that could be used to extract personal information from user input, it does not seem feasible to implement the adaptive user profile. Despite being one of the core design concepts to enable adaptation towards the user, it has been decided to omit this feature within the first prototype.
- **Authentication**: This aspect is such a basic functionality for almost any application and service that implementing it would just mean to be more work in developing the prototype without any value added with respect to demonstrating the value of the mental health promoting artificial companion. Therefore, it is not implemented in the prototype.
- **Data import/export functionality**: Same as with the authentication, the possibility to import or export data from an application has been sufficiently proven and has become a basic functionality. As the aim of developing the prototype is to get a first impression, how a mental health promoting companion for students could look like and how it would be supporting students, adding this functionality does not seem to be resulting in any improvement in usefulness. Therefore, this functionality has been omitted for both the mental health data as well as for the personal user data.

4.2 Core components for the prototype

The aim of the prototype is to create a first impression of the designed concept for the mental health promoting companion for students with limited functionality that will enable user tests and, based on the user feedback, further develop the application.

After having made clear which parts of the concept will not be part of that first prototype, it is time to list what is going to be implemented:

- **The Core-Buddy-Module**: As this represents the "heart" of the application, including all logic for the companion's behavior, this will be the most important part in developing the prototype. It shall be developed as comprehensively as possible.
- **Mental Health Module**: Together with the adapting and engaging qualities, which are represented through the Core-Buddy-Module, the Mental Health module is one of the central components within the designed concept. One could not gain an impression on how the app works, when the companion is not able to recommend helpful strategies for promoting mental health. Furthermore, the process of

selecting an appropriate intervention for the user's current situation is thought of as one of the central value adding aspects of the companion.

- **User profile**: Though the implementation of the adaptive user profile is not possible, due to the above-mentioned reasons, the prototype should still contain a profile for the user and implement the behavior of the Core-Buddy-Module using the information about the user from the user profile. Instead of being adaptive, this will be a fixed user profile, only consisting of the user's name and the history of mental health interventions done and their respective rating.
- **Ethical aspects**: Even though it is only a prototype, a user might still get the impression that the companion is improving mental health. Within the scope of what is possible, ethical aspects shall be already implemented within the prototype. For example, it should contain a disclaimer informing the user of the most important aspects, such as what to expect and not to expect from the prototype, which data is collected, how it is processed and finally, make clear that this application cannot substitute any human mental health professional. Furthermore, it should contain a list of mental health contacts.
- **Basic UI**: With the limitations mentioned within the last subsection, it will not be possible to create a lively image of the companion's avatar. Nevertheless, the companion should have some form of embodiment in the form of static images that change depending on the situation. As neither STT nor TTS will be part of the prototype, the companion shall be communicating only through text messages written on the screen and the user can answer by using textual input.
- **Emotion Recognition**: Adapting to the user is not possible without getting any contextual information about the user. Consequently, the proactive nature of the companion that checks in with the user when they are not feeling well cannot be put into practice without any form of emotion recognition. To demonstrate this behavior without the need of extensive work in searching for lightweight, non-discriminating, fast and accurate emotion recognition models and adding them to the application, the author decided to make use of an API for facial emotion recognition. This API was kindly provided by Beyond Emotion[12], a software startup founded by two former graduates of the University of Applied Sciences Hamburg. After having been part of the "Emotion Bike" Project at the university, in which they gained initial

[12] Find more information on: https://beyond-emotion.de/ . All emotions that can be recognized by the provided API can be seen in Appendix 6.

insight into facial emotion recognition, the two founders used this knowledge to further develop an emotion-recognition product.

- **Text Processing**: While the use of a LLM should not be implemented within the prototype, text processing in general should be implemented – as the individual text processing lays the groundwork for adaptivity to user and context. Furthermore, the friendly, proactive nature of the companion could not be demonstrated without any form of textual output. As free generation of textual responses is not possible without the use of an underlying LLM, the text processing will be relying on prewritten sample texts. For the user-input, either free text typed into a text field or predefined options, which can be select via buttons, shall be used.

4.3 Technical description of the prototype

This chapter will be equivalent to the design chapter, first describing the implemented components, then having a look at the resulting architecture and state machines. Finally, communication between the different components is described to get a better understanding of how the application works.

4.3.1 Components

During the development process it came out that the Core-Buddy-Module, as defined in the design, was covering too many responsibilities. The plan was that the Core-Buddy-Module would be the orchestrator of almost anything in the app, with almost all data flows coming together, and sometimes just being redistributed to other modules. As multiple responsibilities within one module contradict with the single responsibility principle, which is one of the main concepts of clean architecture, it can be criticized that this has not been noted earlier. But as always, knowing a theory of clean architecture does not always result in being able to directly put these principles into practice. At least, this has been noted during the development process and hence, the Core-Buddy-Module has been split into several other modules:

- **BuddyStateMachine**: This module represents the central state machine which is responsible for the companion's behaviour. It processes events, transitions as defined and triggers any actions that need to be executed on entry, exit or transition. Furthermore, it updates the UI based on the current state.
- **EventDispatcher**: This module serves as the central event-queue, in which all the other modules can feed events to be processed by the BuddyStateMachine.

- **StudySessionTracker**: This module keeps track of the student's study session. It starts a timer, when a session begins and, when student studied too long, notifies the BuddyStateMachine by sending an event via the EventDispatcher.
- **EmotionProcessor**: This module keeps track of the student's emotions during a study session. It processes the emotions identified by the Emotion Recognition module and identifies, when most of the emotions within a certain period of time are evaluated as negative. In consequence, it notifies the BuddyStateMachine by sending an event via the EventDispatcher.

With the introduction of these four modules, responsibilities were clearly separated. As the Core-Buddy-Module became obsolete, it was completely cut out from the final design of the prototype.

During the exploratory testing it became clear that it would be useful to change settings while the application was running. Hence, the SettingsManager component was added. This component is responsible for keeping track of the application's settings, such as the interval for emotion recognition or the enabling and disabling of the emotion recognition functionality. The latter was introduced to give user's more control over their collected data, as this seemed to be one aspect noticed as critical when talking about the project with other peer students.

The final resulting architecture of the prototype, including the necessary components for the user interface (BuddyScreen and BuddyViewModel) as well as the interfaces to prevent tight coupling, will be illustrated within the next chapter.

4.3.2 Architecture

The following Diagram 7 gives an overview of the app's architecture. For better readability, it has been added to the Appendix 7at full size.

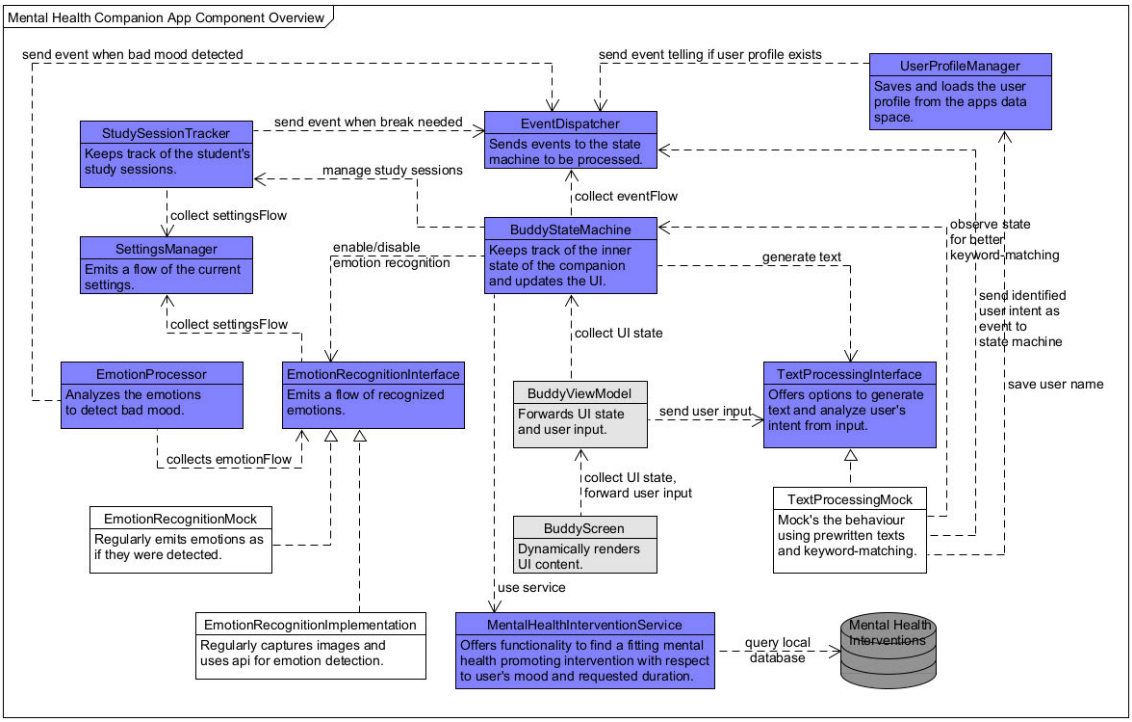

Diagram 7: Overview of the architecture of the implemented prototype

To make the diagram clearer different text and background colours were added to the diagram:

- **UI-Modules** are marked with light *gray background color*
- **Background-Logic-Modules** are marked with *blue background color*
- **Mock-Implementations** or Implementations that vary much from the initial design and need to be replaced before publishing the app are marked with no background colour

Is it can be seen from the architecture diagram, the BuddyStateMachine, together with the EventDispatcher, still form the core of the companion application, as they hold the central logic and emit the UI state.

But, in contrast to the prior design, the other components directly communicate with each other, were applicable. For example, the EmotionProcessor directly collects the flow of emotions, which is emitted by the EmotionRecognitionInterface, and sends the BadMoodDetected event to the EventDispatcher only after having detected that the user might be in a bad mood. In the meantime, the BuddyStateMachine does not need to care about processing all emotions recognized by the EmotionRecognition module.

Similarly, any changes in the settings, such as a change in the interval for emotion recognition, enabling/disabling the emotion recognition completely and the time, when the user wants to be notified to make a break, are emitted by the SettingsManager and directly collected by the components, which need this information.

For the MentalHealth module, both the MentalHealthInterventionService and a local database with MentalHealthInterventions has been implemented. This simplifies the search for an appropriate mental health promoting intervention, as the respective service can directly query the database. The MentalHealth database also contains user data for the mental health interventions, such as the times done in total, the last time done and the average user rating. This implementation contrasts with the designed specification in which the mental health user data should be part of the user profile, but during the implementation of the MentalHealthInterventionService it became clear that the proposal of an appropriate intervention would be easier if the data was stored in the same database.

Together with the interfaces used for emotion recognition and text processing the architecture shows a modular approach which will be easy to adjust, expand and maintain in the future.

According to the MVVM approach, the application clearly separates between model, view and viewmodel. But in contrast to the usual MVVM pattern, the viewmodel serves only as a forwarder and state-holder for the UI, not holding any business logic.

4.3.3 State machines

Similarly to the insights of the application's architecture, shortcoming within the state machine design have been noticed during development. For example, the whole introduction path, when the user opens the app for the first time, has not been respected within the CompanionMode diagram. Another problematic aspect was that the designed path of handling ExtendedStudyTime and BadMoodDetected events could have resulted in a repetitive behaviour of the companion, in which it keeps on asking the same questions and proposing the same solutions over and over again. This would have been completely contradictory to the intended behaviour of the companion to be adaptive to the situational context. Consequently, a reasonable behaviour was introduced for these situations.

Within the following sections, an overview of the implemented state machines will be given. As with the missing of an authentication module, the process of logging in into the application could not be implemented, the corresponding state transitions as described in Diagram 2 have not been developed further. They exist within the code, but for the prototype the user is always seen as being authorized. Therefore, explanations begin with the CompanionMode, which can be seen in the final version in Diagram 8:

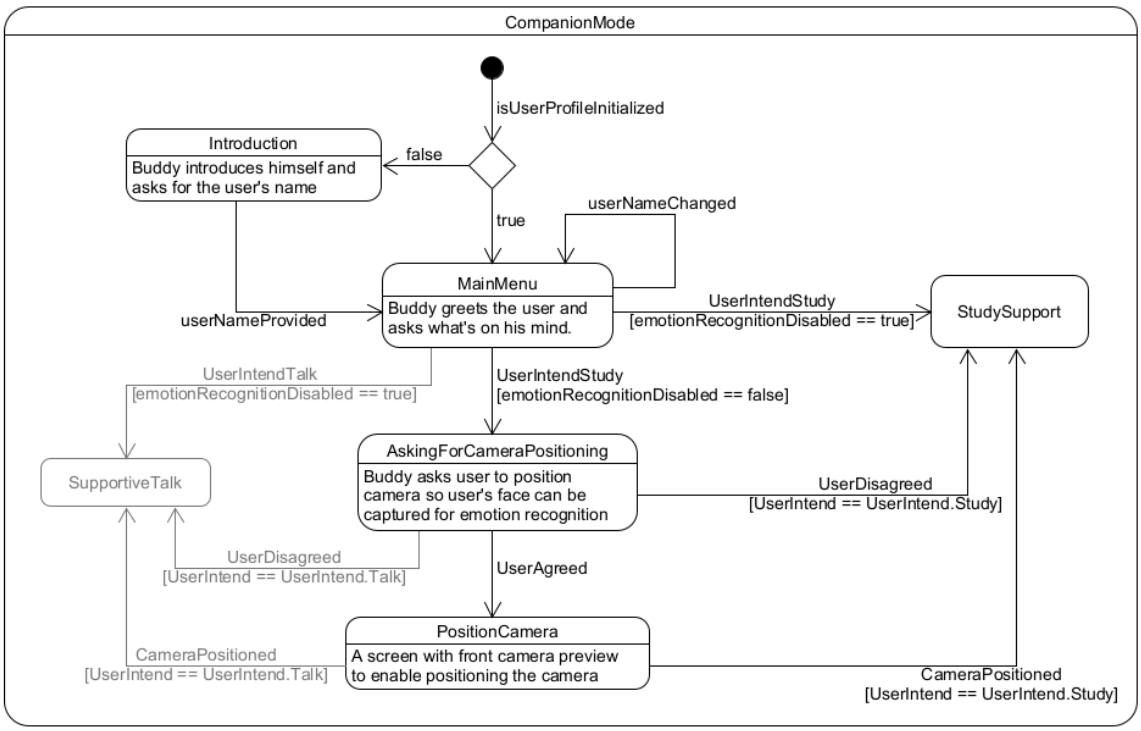

Diagram 8: Final state machine design for the companion mode

When a new user opens the app, the application will check, if there is an existing adaptive user profile, which is already initialized with a username. This is done by the UserProfileManager. If this is the case, the BuddyStateMacheine transitions to the MainMenu state. This is the state, in which the companion (called "Buddy" within the diagram, as this is how it got named) greets the user and asks, what they want to do.

If the username is not initialized, the companion introduces itself and asks for the user's name. From the MainMenu, the user can either start a SupportiveTalk or StudySupport session. The first is to chat with the companion and share some issues that might be weighting the student down and preventing them from starting to study. The second is to start a study session, in which the student is accompanied by the artificial companion. If the emotion recognition is generally enabled, the companion will ask the user to position the camera so it can see their face. If the emotion recognition is entirely disabled, which can be individually set by the user on a separate settings screen, the study session directly starts.

Within the diagram, the transitions to SupportiveTalk have been marked with gray color to indicate that while these transitions theoretically exist, they are not functionally implemented in the prototype. The attempt to build a useful, adaptive, emotionally intelligent and empathetic dialog logic representing the SupportiveTalk mode was made, but needed to be declared as unsuccessful. As the prototype does only contained a mock of the TextProcessing module, the author tried to use keyword-matching mechanisms and simple follow-up questions for the supportive talk mode. Exploratory tests executed during the development process showed that this did not result in the impression of interacting with a curious and empathetic companion, but rather gave the feeling of interacting with a "stupid chatbot". As this impression should be prevented in any case, when the prototype was presented to any real users, the author decided to not include the SupportiveTalk mode in the prototype. Instead, all focus was put into designing a comprehensive and thoughtful StudySupport mode. The result can be seen in Diagram 9. For better readability, it has been also added to the Appendix 8.

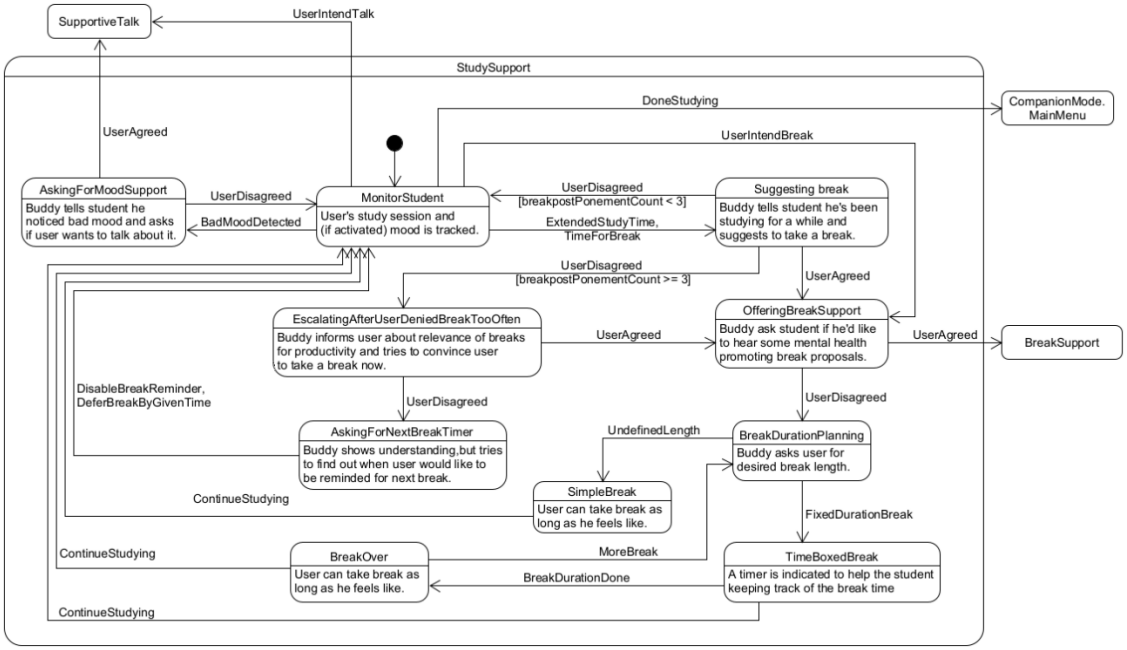

Diagram 9: Final inner design for the StudySupport mode

As it can be seen from the diagram, the companion's behaviour within the StudySupport state is now more elaborated than it was in the initial design. For example, when the user denied to take a break three times, the Companion will try to nudge them to take a break. If the user still denies to recharge, the companion will ask the user, when they want to be reminded the next time, so that it does not keep on "stupidly" asking the user to take a break. Furthermore (and which cannot be seen from the diagram), after the initial break reminder, which triggers on the time set for through the settings, the time for each next reminder is halved – assuming that we should not wait twice the maximum study time before taking a

break. To still give the user control about this nudging behaviour of the companion, they can reply they do not want to be reminded at all, when the companion asks for the next break timer. This completely disables further reminders for the rest of the study session.

To prevent repetitive transitions into the AskingForMoodSupport state, the EmotionProcessing module was programmed to have a "cooldown"-logic. This means, after initially detecting a negative mood in the user and sending the corresponding event to the BuddyStateMachine, it will deactivate the sending of this event for a certain period of time, which is currently set to 20 minutes. The underlying idea is that, if a user does not want to talk about their negative mood in the moment, they probably won't want to do this in the next minute. But, as the companion should show caring behaviour, it may appear natural to check in with the user again, after a while. If the user still denies to talk about it, the cooldown gets halved for the next reminder, applying a similar logic as with the break reminder. Additionally, the cooldown resets, when the EmotionProcessing module notices an increase in user mood – assuming, that the next time a negative mood will be noticed it might be for some other reasons and the companion should check in with the user to ask them about it.

For the BreakSupport state, the concept has been put into practise as it was outlined within the design chapter. Therefore, there will be no revised version of this diagram discussed. As the SupportiveTalk state could not be implemented, because of the above mentioned challenges, it also won't be further discussed here. Instead, the next section explains, how the different parts of the aplpication work together to create the companion's behaviour.

4.3.4 Component interactions and data flow

Within the last three subchapters it has been explained which components have been implemented in the prototype of the mental health promoting companion application and how the final architecture and state machines of the prototype look like.

While being sometimes mentioned in sidenotes, it has not yet been explained in a structured manner, how the different components of the app work together. This shortcoming shall now be addressed by providing an overview of the interaction between the app's core components, illustrating how they collaborate to realize the envisioned functionality. This will be done by having a look at the following three sequences:

1. Buddy output generation & user input processing
2. Detecting, when user should be reminded to take a break
3. Detecting bad mood in the user

As these make up the core functionalities of the app, the reader should have a very good overview of the app's inner functioning, when having understand these sequences.

The first sequence, as can be seen in Diagram 10, shows how the companion's output is generated and how user input is processed. This diagram can be seen in Appendix 9 at full size.

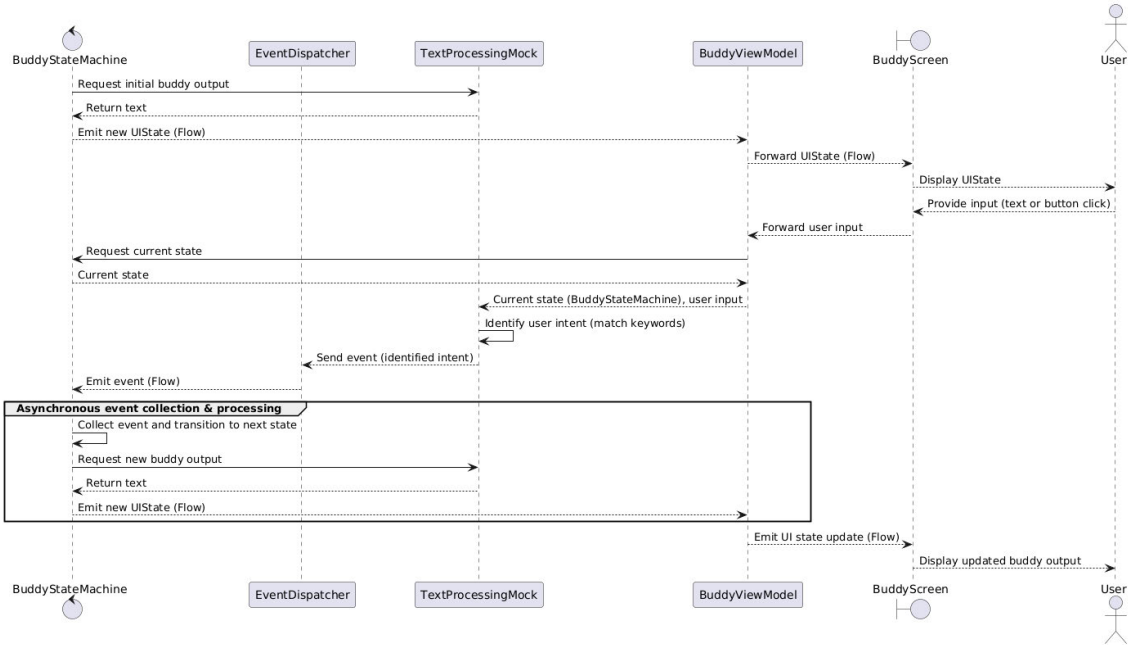

Diagram 10: Sequence diagram of the companion's output generation and user input processing

As it can be seen from the diagram, the BuddyStateMachine uses the TextProcessingMock to receive text that can be shown on the display as buddy output. The user reacts to the output by writing text into the text input field or clicking on a button with a predefined user input. This user input is forwarded, together with the BuddyStateMachine's current state, to the TextProcessingModule, which identifies the user's intent from a given list of possible intents with according keywords. The identified user intent is then sent to the EventDispatcher, which emits it to a flow of events that is collected and then processed by the BuddyStateMachine to trigger the next state transition. From there one, the process starts over again.

The following Diagram 11 gives an overview of the Study session tracking and break suggestion process. It can be seen in Appendix 10 at full size.

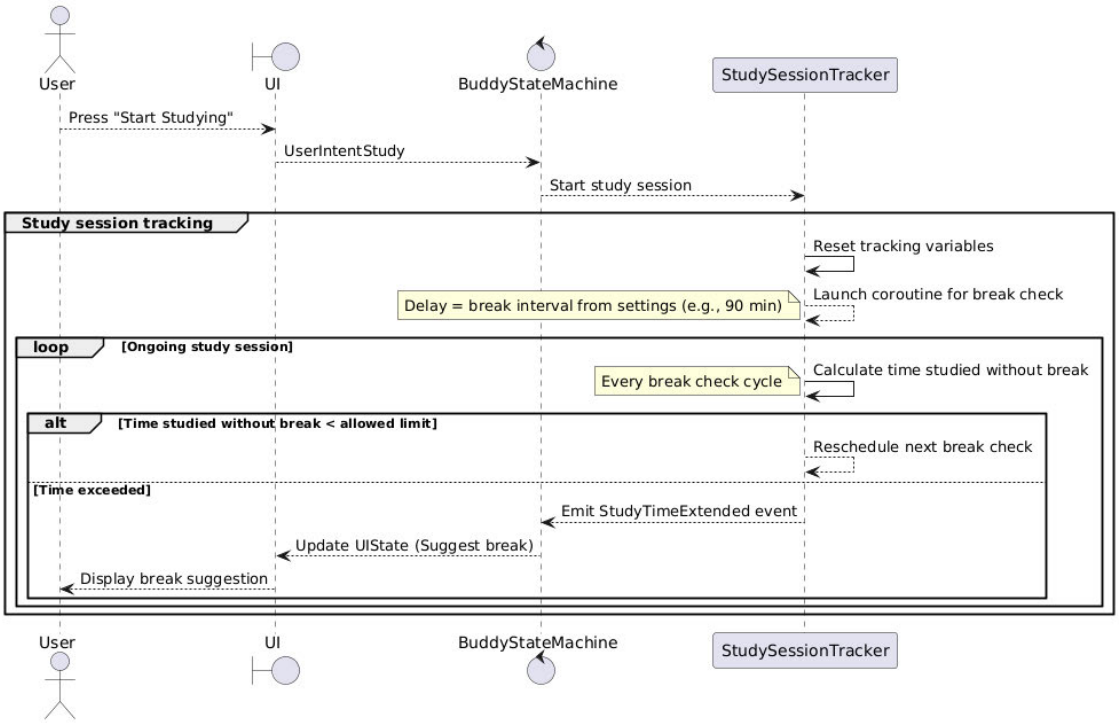

Diagram 11: Sequence diagram of study session tracking and break suggestion process

For the detection of when the user studied too long without taking a break, the BuddyStateMachine makes use of the StudySessionTracker. Whenever a student tells the *companion* they want to start learning, the BuddyStateMachine calls a function in the StudySessionTracker to start a new study session. The StudySessionTracker than uses the information about the maximum study time without breaks, which it got from the SettingsManager's flow of settings, to initiate a new coroutine task, that will check the time studied without breaks after that timer has been exceeded.

In case that the student already took a break on their own initiative in between, the check will result in setting a new timer, this time calculating from the last time the user started studying after taking the break. When the student did not take a break so far, the StudySessionTracker will send the event "StudyTimeExceeded" to the BuddyStateMachine (via the EventDispatcher), which will result in the BuddyStateMachine transitioning to the SuggestingBreak state. To simplify the diagram for better readability, the BuddyScreen and BuddyViewModel have been merged to one participant called "UI", while BuddyStateMachine and Eventdispatcher have been put together as "BuddyStateMachine". Furthermore, the TextProcessingModule has been completely omitted as its role has already been sufficiently explained within the previous diagram and adding more interactions for text analysis and generation would not have added any explanatory value to this diagram, which focuses on how the student's study time is tracked to make suggestions at the right time.

Furthermore, this diagram only contains the process of suggesting a break, not the process of reacting to the user's response. Adding all possible combinations of user response regarding taking a break, postponing a break or taking a break on their own initiative would have completely overloaded this diagram with details and alternatives. But for understanding, how the BuddyStateMachine works together with the StudySessionTracker, the degree of abstraction of the diagram is exactly appropriate.

To get a better understanding of the break relevant possible user interactions with the *companion*, it is recommended to have another look at the state machine of the StudySupport state, which has been explained right before in section 4.3.3.

For now, the last sequence, that has been announced, should be highlighted. It illustrates, how the BuddyStateMachine acts together with the EmotionRecognitionModule and the EmotionProcessingModule to get notified when the user might not be feeling well. For this Diagram 12 the same abstractions as in the previous one have been made. As the priorly explained diagrams, it can be seen in full size in Appendix 11.

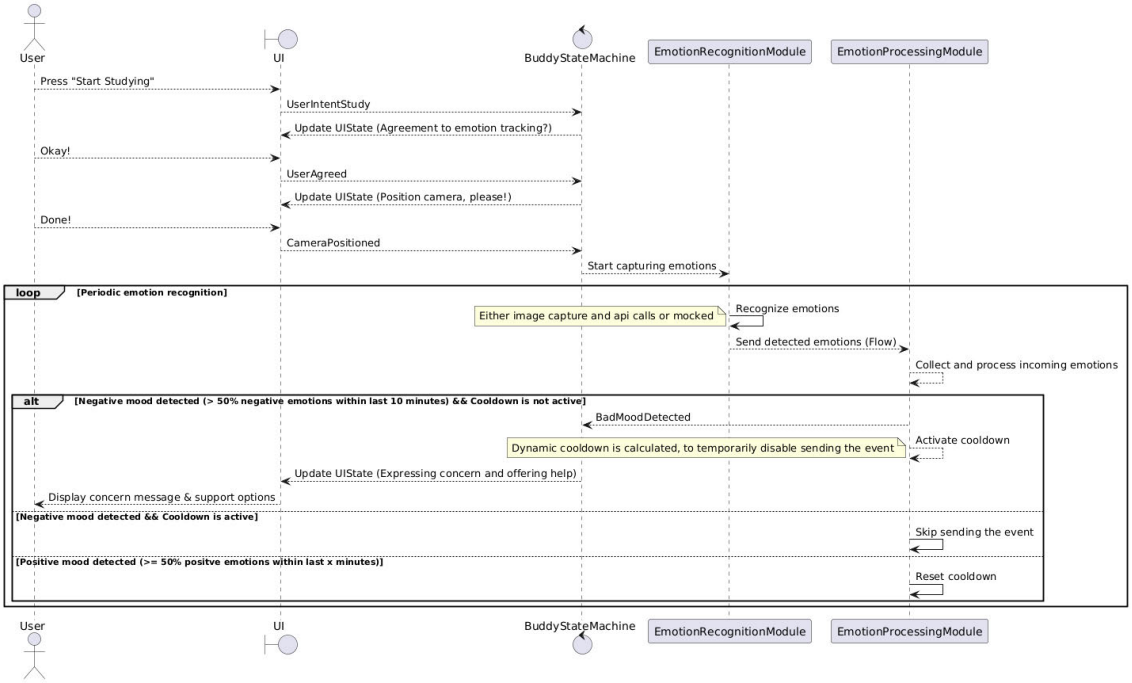

Diagram 12: Sequence diagram of emotion monitoring and bad mood detection process

As it can be seen from the diagram, after the user agreed to mood tracking and positioned the camera so that the application can capture their face, the BuddyStateMachine initiates the emotion capturing in the EmotionRecognitionModule. This starts the periodic background task to either take images and send them to the API for emotion recognition or the

mock implementation, which just periodically emits a reasonable list of emfotions.[13] As soon as the EmotionReconitionModule emits emotions, these are collected and processed by a coroutine in the EmotionProcessingModule. Its functioning has already been explained sufficiently within the last subchapter 4.3.3, therefore it will not be repeated here.

4.4 Description of the prototype with respect to the main design aspects

After having gained an in-depth understanding of the technical implementation of the application's prototype within the last chapter, this chapter explains and discusses the implementation in reference to the design considerations that have been explained in chapter 3.2. For curious readers, who want to get some insights into how the final result of the developed prototype looks like without the need to import the project into their IDE and run it, some screenshots of the application have been added to the Appendix 12.

4.4.1 Appearance

Figure 4: Avatar of the companion greeting the user

Figure 5: Avatar of the companion reading during a study session

The image-generation tool Midjourney [76] was used to create a first draft of how the avatar could look like. The plan was to create multiple static pictures of that character with different emotional expressions with respect to facial expression and body posture to indicate mood changes in the companion.

Unfortunately, creating variations of a consistent character was not feasible – neither with Midjourney, nor with other image-generation tools tested by the author. The closest result was generated by Adobe's Firefly image generation tool [2], that provided an image, which

[13] As it was not intended solely rely on the API, which was kindly provided by Beyond Emotion, a mock implementation of the EmotionRecognitionInterface has been implemented for testing the prototype. It relies on a simple mechanism to regularly emit a list of emotions from the same category of mood state (positive/negative etc.). Furthermore, it only changes from one mood state to an adjacent one, so e.g. from positive to neutral or from neutral to negative – but never from positive to negative.

was at least close enough to the original so that a user would not notice the difference in an instant. Therefore, this image was used as a second image option in the app. Figure 4 and Figure 5 (see above) show the two resulting images. Both images were manipulated with the open-source image editing tool Krita [59] to have a version of the companion's avatar without background. The first image, generated from Midjourney, was generated with the prompt:

> "Create a friendly and approachable avatar for a mental health companion app. The avatar should be a cute, modern robot with large, expressive eyes and a warm smile. Use a soft, cartoonish style with rounded edges to make it non-threatening and universally appealing. The primary colors should be soft blue (#E3F2FD) and white, with accents of calm blue (#2196F3) and green (#4CAF50). The robot should have a clean, modern design, exuding warmth and supportiveness. It should look empathetic and motivational, ready to listen and offer encouragement. Include details that reflect a calm and knowledgeable personality."

It took the author various regenerations and variations until the tool came up with the solution that can be seen in Figure 4. The same applies to the second picture, generated by Adobe Firefly: Here, the author used the first picture as both style- and composition-reference, added the following prompt:

> "A friendly and approachable avatar for a mental health companion app. The avatar should be a cute, modern robot with large, expressive eyes and a warm smile. The robot is sitting on the ground and reading a book. His legs are stretched in front of him, tips of the feet directing upwards. In the image, we can see his full body from the side. Use a soft, cartoonish style with rounded edges to make it non-threatening and universally appealing. The primary colors should be soft blue (#E3F2FD) and white, with accents of calm blue (#2196F3) and green (#4CAF50). The robot should have a clean, modern design, exuding warmth and supportiveness. It should look empathetic and motivational, ready to listen and offer encouragement. Include details that reflect a calm and knowledgeable personality."

As with Midjourney, several iterations were necessary until the result was generated.

Although with these static pictures it is not possible to let the companion communicate non-verbally, they at least give an impression of how the companion's outer appearance could look like. Furthermore, with the second picture of the reading companion, it is to show some change in the companion's behaviour while being in a study session.

4.4.2 Personality

In the current prototype-version, there is no dedicated class to represent the companion's personality. Instead, it is implicitly derived from the set of possible quotes that are used for the companion's textual output. To make the user experience and the companion's

communication style be less predictable and seem lively, the author used ChatGPT-4o to create a set of 232 sample texts in total, with around five to ten sentences for every state.

For the creation of these texts, the author introduced the GPT-4o model to its role as a mental health supporting study companion and instructed it to create several sentences to match the intended style in every situation. When the initial set of generated sentences did not match the intended style, the author instructed the LLM to refine them.

One now might wonder, why the author did not produce the sentences herself. The answer is simple and comprehensible: As the designed concept intents to let all output of the companion being created by a LLM, the closest way to mock this behaviour is to let the sentences be prewritten by a LLM. The sample texts can be read in Appendix 13.

4.4.3 Communication

As already mentioned, the decisions regarding the scope of implementation of the concept result in a very limited range of communication for the mental health companion. It is neither possible to freely chat with the companion using textual input, nor is it capable of communicating via spoken language or nonverbal expressions. Instead, the current implementation of the prototype uses a "text and button" approach in interacting with the user. Instead of "talking", everything the companion says is printed as text on the screen. Instead of "replying" the user has the option to press buttons, which's textual description is than processed as if it was free user input.

4.4.4 Adaptivity

Within the developed prototype adaptivity is created towards the user, as the companion remembers the user's name and, if enabled, current emotional state. Adaptivity towards the context is created, as the companion's greetings are daytime-specific (while also adding random greetings, that can be said to any time of the day, to create more "natural" interactions) and that the companion, through the help of its inner state machine, has some knowledge of what is currently happening. For example, if the user is studying, the companion tracks when the user started the session or how long the user has been studying without breaks. It uses this information as context, when interacting with the user and therefore is already, to some extent, adaptive to user and context.

4.4.5 Engagement

While the implementation of main aspects such as communicational skills and adaptivity might be questioned, the engaging capabilities of the developed prototype cannot be denied. Both two planned events, namely BadMoodDetected and StudyTimeExtended, have been implemented. Consequently, the companion proactively checks in with the user on having

detected that the user might not be feeling well or has studied for too long without taking a break. Furthermore, when a user denies taking a break several times, the companion softly tries to nudge the user to notice the importance of recharging for being productive at work.

4.4.6 Ethical considerations

Last, but not least, it should be addressed how the ethical considerations that have been extensively discussed in chapter 3.2 have been considered in the implementation of the prototype.

The contribution to society and human well-being that the ACM wants to encourage in each developer does not need to be further explained, as one of the major goals for both the conceptual as of the practical implementation has been the wish to contribute to human-well-being.

Regarding the potential risk of excessive emotional attachment, the design makes it clear that the author does not intend to create a substitute for human companionship. Instead, the companion is meant to provide support in phases where human companionship is not available. Furthermore, the companion should actively encourage the user to care for their real-life social connections. This aim has already been implemented to some extent in the prototype: Four of total 40 default mental health promoting interventions, that have been introduced in the prototype, aim at fostering the user's connection to other humans. For example, the companion suggests contacting friends, sending a gratitude message to a friend or to write down a positive memory of an interaction with a friend.

To prevent potential harm that might be caused by users mistakenly believing that the companion could replace a professional therapist, the author included a disclaimer (see Appendix 14). It clearly states that the companion cannot substitute any human mental health professional and furthermore, cannot guarantee any improvements in mental health. Furthermore, within the disclaimer users are tried to be encouraged to seek professional help. To lower potential barriers to do so, the app contains a short list of the most important mental health contacts, both for emergency situations and for seeking support in general (see Appendix 15). As people going through an acute crisis might be overwhelmed with the plenty of information that is out there in the world wide web, this list is kept very short on purpose, offering three options each, with helpline contacts that can be directly dialled from the application.

In addition to the disclaimer in terms of the limitations of what the app can do for the user, the initial info box also contains information on the background in which the app has been developed, that it is currently just the prototype for a bachelor's thesis and that any feedback or input is highly appreciated.

5 Testing the developed prototype

Within the last subchapter, the implementation of the prototype for the proposed companion application has been explained. This chapter focuses on how it has been tested and evaluates to what extent the requirements, as described within the design chapter, have been met.

5.1 General aspects of software testing

The aim of software testing is generally twofold: First, testing shall assure that the software functions as intended. Second, possible bugs and errors shall be identified as early as possible, to minimize the resulting risks in the future[14].

In general, one can say that exhaustive testing is not possible in any software project. Therefore, it must be evaluated which tests are seen as being useful with respect to costs of developing this test now or future costs that might result in not having identified the errors.

Within the development cycle, usually the following steps of testing are being conducted:

1. **Component testing**: Testing single functions, classes or components on their own, making sure they work as intended when being isolated from the other software components. This is usually done with unit tests and testing frameworks and aims to find errors in the implementation of single components and make sure they are developed in a robust way, for example by being able to handle invalid input data.
2. **Integration testing**: Testing the interaction of components, making sure they work together as intended. - With respect to the testing drivers this is similar to the component tests, but additional logging is required to track the data transfer between components. Integrating testing aims at identifying errors that couldn't be found earlier, for example different interpretation of data objects across modules or errors resulting from timing issues.
3. **System tests**: Testing the system as a whole and checking if it meets all the requirements that have been drawn up. For this, the complete software should be running in a testing environment similar to the productive environment. System tests aim at detecting failures from incorrect, incomplete, inconsistent implementation of requirements and identifying requirements that have been forgotten in the documentation.

[14] All theoretical explanations with regards to software testing are based on the script and the author's knowledge gained from the course "Certified Tester" from Prof. Bettina Buth, which the author took part in in winter 2022.

4. **Acceptance tests**: These tests are conducted in a real productive environment and include future users of the application. They aim at assuring that the software meets the user's expectations and accords to predefined standards.

Testing strategies with respect to the integration of multiple components can be either "bottom-up" or "top-down". Within the first approach, first the base components are developed and tested, and next, higher-level components are tested that can use the already existing and tested components. For the second approach, first the higher-level components are tested by using stubs for underlying components.

5.2 Testing approach for this thesis

The above-described testing process in the development cycle was set to practice in a bottom-up approach. As time was scarce, the author tried to use a well-balanced approach with respect to efficiency and test coverage. Therefore, only the most important components have been tested. Namely: BuddyStateMachine, EmotionProcessingModule, StudySession-Tracker and MentalHealthInterventionService.

For the different scenarios, a mixed approach of component and integration tests was used: The EmotionProcessingModule and StudySessionTracker were testing using isolated component tests, with all other dependencies mocked using the MockK[15] library. To assure that the events "BadMoodDetected" and "ExtendedStudyTime" have been sent in the expected amount, a combination of MockK and Kotlin Couroutines Testing library was used, that made it possible to verify the exact number of function calls within a coroutine.

The MentalHealthInterventionService was tested together with the MentalHealthDatabase and the corresponding Database Access Object[16]. The room framework, which was also used for the implementation of the real mental health database was used for creating an in-memory database for the testing scenarios.

The BuddyStateMachine was tested together with the EventDispatcher, as they are so tightly connected that it can be assumed as being one module. Actually, the only reason those two have been separated into different classes is to prevent cyclic dependencies that would have resulted from the fact that on the one hand, some components are injected into the BuddyStateMachine, because it needs to call their methods (such as starting/pausing/ending a study session from the StudySessionTracker) and at the same time the injected

[15] MockK is a mocking library for Kotlin [77].

[16] Database Access Object (DAO) is a design pattern, in which all interactions with the database (DB) are encapsulated by an interface, the DAO. This clearly separates the interactions with the DB from the business logic. Within the Room-Framework, a DAO is needed to interact with the DB. [42].

components component needs to send an event to the BuddyStateMachine (such in this example the event "StudyTimeExtended").

For all Unittests, JUnit was used in combination with the Robolectric framework. As JUnit is widely used amongst developers, this will not be further explained. Robolectric gives access to testing Android based components, such as logging or UI within Unit tests running on JVM. It was used to redirect log statements, which would usually appear within the Logcat window, while the application is running on an Android device, to the System.out console during test-execution.

Regarding the test cases, the most important functionalities for the EmotionProcessor, StudySessionTracker and MentalHealthInterventionService have been tested. A full list of the chosen scenarios can be seen in Appendix 16. For the BuddyStateMachine all relevant transitions of the prototype have been tested. The complete overview of test cases can be seen in Appendix 17, which also gives an overview of the BuddyStateMachine from a bird's perspective. The only transitions that have not been tested are the ones connected to the SupportiveTalk mode, as this mode has been decided to be not further developed within the prototype.

Carrying out the systematic tests described above revealed a few errors that could be fixed immediately, so that the component's functionality with respect to the tested cases can be proudly assured.

5.3 First insights from system tests

As the developed prototype is far away from being feature-complete and several modules have not yet been implemented as intended, it did not seem reasonable to already conduct acceptance tests with real users. But, as the prototype already offers some functionalities, the author did not want to miss the opportunity to conduct at least some exploratory system tests on a real device. Therefore, the companion application was installed both on the author's smartphone and on a tablet from the inventory of the Living Place[17], which was provided to the author by her supervising professor.

The author conducted several iterations of explorative system testing sessions, in which she used the developed prototype in the scenario it was designed for: As a companion during solitary home studying, or more specifically: while the author was writing this thesis.

[17] The Living Place is a special smart home laboratory located at the University of Applied Sciences Hamburg, which aims at researching both modern smart home approaches as well as associated changes in lifestyle and subjectivity.

Testing the prototype in such a real study setting was very fruitful in gathering more insights on the practicability of the app and how students would use the app, which features would be most important and what aspects might need to be added or reworked for the next development cycle.

During the first launch of the application on the Google Pixel tablet it was noted that the UI looked different than on the smartphone to which the application was occasionally launched during the development. Researching this issue resulted in the insight that an element from the official android library used for displaying the side menu, through which the user could access other screens such as the application's settings, was by default programmed to be always expanded on larger devices. This was not intended for the companion application as the user should only see the companion, when interacting with it, to not make the application feel too "technical". This problem could be solved by adding a simple Boolean variable and disabling to show the sidebar completely, when the menu was not opened.

Another issue arising during these first tests was that the devices' display turned off relatively quick after starting a study session. This had several consequences: First, it led to the subjective feeling of "loss of companionship" in the user, as the companion practically disappeared. Second, when the companion changed its state, for example proposing a break, this was not noticed by the student, as it did not result in any changes in the black screen. Finally, and this was only noticed after the author watched the live logs during a testing scenario, the access to the camera was lost when the display turned off as this automatically results in unbinding the camera resources within the framework used. To easily fix this issue and improve user experience in further explorative user tests, display was set to be always on while the application is active.

After having fixed these two issues, the companion was tested in several other study sessions by the author. The following list gives an overview of the author's insights from these tests:

- During the testing sessions the companion checked in with the user quite regularly. The logs showed that it had been detected a negative mood in the user quite often and it felt to the user as if the cooldown mechanism was not working as intended. To gain more insights on this issue, the author first took a close look to the application's logs, which showed that while the cooldown seemed to be working as intended, the BadMoodDetected event was still sent several times shortly after each other, because the cooldown was reset in between. This was due to a shortcoming in the app's logic, which was based on the idea, that when the user was not in a

negative mood state, they must be in a positive mood state. As negative mood was detected, when most emotions within the time interval (default: 10 minutes) were regarded as negative, having less than 6 negative emotional states in the history always resulted in a cooldown reset. This was even the case, when some of the entries within the recent emotion history were empty, for example due to an absent user or when the user looked downwards so that their emotional expression could not be detected. To fix this, the author adjusted the respective part of the code so that only entries which actually contained emotions would be added to the list of recent emotions. Still the question remains, which indicators should be taken into account for resetting the cooldown or if it should be reset at all.

- With respect to the large amount of negative mood states detected in the user, the author added a more in-depth logging of both the images taken of the user and the emotions recognized within these images, as she did not really feel in a bad mood, when the companion was checking in with her. Some of the sample images and the respective detected emotions from the API have been added to the Appendix 18 for illustrating the, from the view of the author, sometimes irritating results of the emotion recognition. While the API used is not part of the developed prototype, this issued highlights the relevance of using highly accurate emotion recognition models in the development of the actual application. Not only did it irritate the user that the companion detected a bad mood so often – from her own experience the author can tell that she even felt worse, when the companion told her she was looking as if she felt down. One hypothesis to explain this feeling is that it might have had an evocative effect on the user. This should be prevented for future users in any case.
- Another aspect noticed during the exploratory user tests was that interacting with the companion, based on reading its quotes on the screen and pressing buttons as a response, did not really feel like interacting with a companion, but more with a "normal application". This reassures the high relevance of the companion's communicative capabilities, which the author sees as crucial to be implemented as designed in future iterations of the development process.
- Last, but not least, the author noticed that she often forgot to interact with the companion during the exploratory user tests. For example, when the user started a break, she forgot to tell the companion, when she was back. One day, she even forgot completely to end the study session, resulting in a logged study session of around 23 hours in the study session history. That the companion did not check in with her, asking if she was back or still studying, further limited the impression of dealing with a real social presence and instead enforced the impression of dealing with a

"Study Tracking App". To prevent this impression in the future, it sounds reasonable to also add some additional logic to the companion's state machine to check, if the length of the study session seems to be reasonable and seek contact to the user, if this is not the case, or if the user might be absent. The latter could, for example, be noticed if a lot of consecutive images captured contain no emotions recognized.

- Despite all the negative points mentioned above, the author felt like the conscious starting of a study session with the companion helped her to concentrate better on the tasks she was doing. Furthermore, when wanting to do a short break, the mental health interventions suggested by the app were perceived as very helpful. Of course, this might be biased to some extend since the author herself added the default interventions to the mental health database – but she cannot deny that the interaction with the artificial companion motivated her to actually put these into practice. After all, simply having the knowledge what might be helpful to increase one's mental health does not necessarily lead to doing it. With the companion friendly reminding the author to keep track of her own mental health, she was motivated to insert small self-care breaks into her work on this thesis.

To summarize the results of the exploratory system tests it can be said that these tests were highly valuable in finding detecting shortcomings of the developed prototype and identify additional requirements, that have been forgotten in the theoretical design of the application. This indicates, that for future development cycles, it is highly recommended to include user feedback and conduct more exploratory system tests with other users to find more potential for improvements.

As a first step to developing a mental health promoting application that is really perceived as companion, communicative capabilities such as free text processing and generation as well as STT and TTS are seen as the most relevant aspects. Without the possibility of naturally interacting with the companion, it is highly unlikely that it will be accepted as such by future users.

6 Conclusion and future work

The present work represents an attempt to address the increasing mental health problems of university students through the development of a mental health promoting companion app. First, the theoretical foundations for the concept have been explored. It turned out that especially two aspects are crucial for social agents to be perceived as companions: adaptivity and engagement. Furthermore, an embodiment, a personality and proper communication skills have been pointed out as the main aspects that need to be kept in mind when developing a companion.

Taking this knowledge, the author outlined an in-depth concept for how such a companion app could look like. In terms of embodiment, the concept aims for creating an animated avatar for the companion that is part of an application for mobile devices to make the companion accessible for many students at lowest possible cost. In terms of personality, the conceptualized companion should be friendly, empathetic and supportive with a special interest in mental health topics. In accordance with the insights from it should behave in a generally predictable way, with a few deviations to increase the perception of liveliness. To make communication intuitive and inclusive in the functional way and adaptive and engaging in a qualitative way, the companion should have both STT and TTS abilities to be able to verbally communicate, but also a multimodal emotion recognition module to be able to react empathetically or even start empathetic interactions. As the author takes ethical aspects very seriously, a detailed section on ethical considerations has also been added to the concept. It would not make sense to repeat this at full length here, but one aspect worth mentioning is the high intention for privacy protection in the outlined concept: It aims to have all necessary models such as emotion recognition, speech processing and a large language model for text processing running on the device so that the user can be sure that their data is not forwarded to any company and hence, they can freely and openly interact with the companion.

While the design that has been illustrated comprehensively from the theoretical point of view, the author's efforts in putting this vision into practice still seem to leave room for improvements, mainly because the developed prototype lacks both the recognition and the communicative capabilities that would be necessary for an intuitive interaction with the user. Nevertheless, the developed prototype does a good job in illustrating the general design approach and the intended engaging behaviour of the companion. Furthermore, the modular architectural approach of the prototype's implementation lays a good fundament for future improvements and expansions in functionality.

With respect to possible future work, the author sees several areas that might be of special interest with respect to the further development of mental health promoting companions for university students:

- Developing non-discriminative emotion recognition models with high accuracy and low resource demands would lay a groundwork for equip the companion with the intended emotion recognition capabilities
- For the further development of the prototype, it appears to be a worthwhile goal to equip the companion with communicative capabilities such as free text generation and processing and both STT and TTS to enable intuitive communication with the user. After having done this, a set of user tests could be conducted to gain more insights on the most important aspects from the view of the users
- It would be an interesting topic to add an animated character to the application and compare the perception of the companion with an animated avatar with the perception of the companion lacking the animated avatar.
- With respect to promoting the student's mental health it might be a good idea to talk with mental health experts as well as students to gain deeper insights in what really helps and what really matters to promote mental health. Although the theoretical chapter within this thesis was quite comprehensive regarding this aspect, there might be more sides to this topic, such as the reasons for and effects of procrastination and their influence on mental health, which have not been addressed yet.

As a last conclusion, this thesis represents an ambitious piece of work within the highly interesting field of affective computing. Taking the existing problem of prevalent rise in mental health issues amongst university students as inspiration to come up with the proposal of a solution, the author gave a comprehensive overview of her research with respect to mental health promotion and artificial companions.

Within the thesis a comprehensive design has been developed which not only focuses on relevant aspects from the technical point of view but also addresses ethical concerns in a comprehensive way. Furthermore, with her sometimes-narrative style, the author shared the story of how she did put this idea into practice and which challenges were to be faced. While the developed prototype might be far from feature-complete in the end, it lays a solid groundwork for future research within the field of mental health promoting artificial companions.

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Appendix

Appendix 1 Full list of example interventions to promote mental health

Name	Description	Category	Source
small indoor workout	do a small indoor workout, beginning with stretching exercises and continuing with some strengthening exercises	physical activity	[13]
fast walk	go outside for a short, fast walk around your surroundings	physical activity	[19]
active yoga	do a small active yoga break	physical activity	[22]
jogging	go outside for a short active jogging session	physical activity	[3]
dance break	play some music that makes you want to move and just freely dance around your room	physical activity	[13]
healthy snack	prepare yourself a healthy snack	healthy diet	[17]
drink water	drink a glass of water	healthy diet	[10]
delicious tea	prepare some delicious tea for yourself	healthy diet	[6]
feel-good treat	enjoy a guilt-free, delicious treat	healthy diet	[2]
power nap	do a short, energizing power nap	sleep routine	[10]
legs up high	relax yourself while placing your legs up high against a wall or placed onto a chair	sleep routine	[8]
catching day-light	go outside to soak up some daylight to sup-port your circadian rhythm	sleep routine	[21]
nature time	go outside and find a green space (e.g. park or forest) and spent some mindful time there.	nature	[9]
little nature time	find any plant close to you (like a houseplant, a tree in front of your window) and mindfully look at it	nature	[5]
listening to nature sounds	open your window or go outside and listen to the sounds of nature, like wind, birds, trees - if going outside is not an option, play and listen to your favourite nature sounds	nature	[25]
contact friends	take some time to let your friends know, they're important for you - by calling them or writing a text message.	connection to others	[12]
gratitude message	Take 3–5 minutes to send a quick message of gratitude or appreciation to a friend or family member.	connection to others	[10]
micro catch-up	Call or text a friend or loved one for a brief check-in. Even a short exchange can boost connection.	connection to others	[10]

connection reflection	Write down 1–2 positive memories of recent interactions with others or reflect on someone you appreciate.	connection to others	[26]
short meditation	take some time for a short free or guided meditation	self-soothing	[11]
belly breathing	take some time to take calming deep breaths into your belly	self-soothing	[10]
4-4-4 breathing	take some deep breaths, holding your breath in-between	self-soothing	[10]
alternate nostril breathing	close your nostrils with the fingers and alternately inhale and exhale through only one of them, then change	self-soothing	[7]
mindful breathing	sit down comfortably, close your eyes and just watch your breath as you mindfully inhale and exhale	self-soothing	[1]
4-7-8 breathing	a relaxing breathing technique, with short inhales, long exhales and a medium break in-between	self-soothing	[27]
listen to a song you like	listen to a song you like, e.g. something relaxing, or an uplifting song and just feel the music	self-soothing	[16]
reading	relax while reading an interesting article or a chapter of a book you like	self-soothing	[16]
creative scribbling	take a piece of paper and some pens and just draw or scribble what comes into your mind	self-soothing	[16]
gratitude journaling	write down three things you're grateful for	positive thinking	[20]
reframing the situation	even if it's tough, see if you can find one small positive aspect	positive thinking	[14]
positive thought swap	take a moment to catch a negative thought (e.g., "I'm so behind") and reframe it into something constructive (e.g., "I'm making progress at my own pace")	positive thinking	[15]
small reward planning	think of some small reward you might give yourself after finishing today's work, so you have something to look forward to	joyful activities	[24]
joyful activity planning	plan an activity that you like to look forward to this week, like meeting a friend, spending some time on your favourite hobby, spending time in nature or whatever you like to do	joyful activities	[23]
send a kind message	send a kind message to someone—just a few words can make a difference	kindness	[28]
giving a genuine compliment	think of something positive about someone (it might even be yourself!) and give this person a genuine compliment, either personally or via a text message	kindness	[19]

explore something new	take some time to try something new. it might be a new music genre you've never heard before, some facts you didn't know, a new sport or anything else you've never tried or seen.	openness	[18]
go different ways	take a walk outside but try to avoid any ways you usually go. try to see, if there's something new to explore you've never seen before.	openness	[10]
switch perspectives	think of a recent situation and try to see this from a different perspective, e.g. of a child or someone from another culture. how would they see this?	openness	[4]
mindful drinking	prepare yourself a nice drink, like a warm tea or coffee and mindful enjoy it with all your senses. do nothing else.	mindfulness	[18]
mindful eating	prepare yourself a nice snack or meal and mindful enjoy it with all your senses. do nothing else.	mindfulness	[18]

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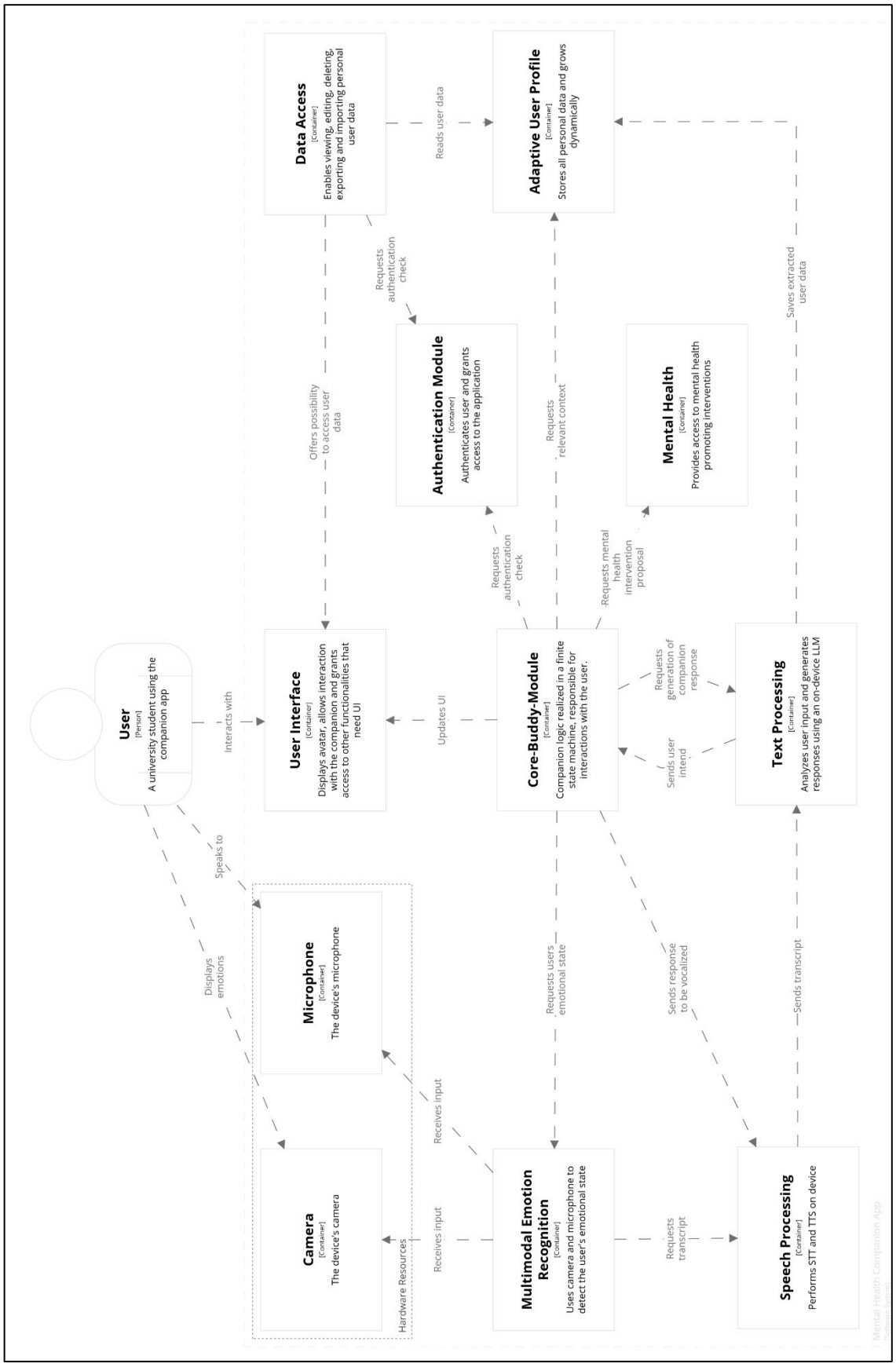
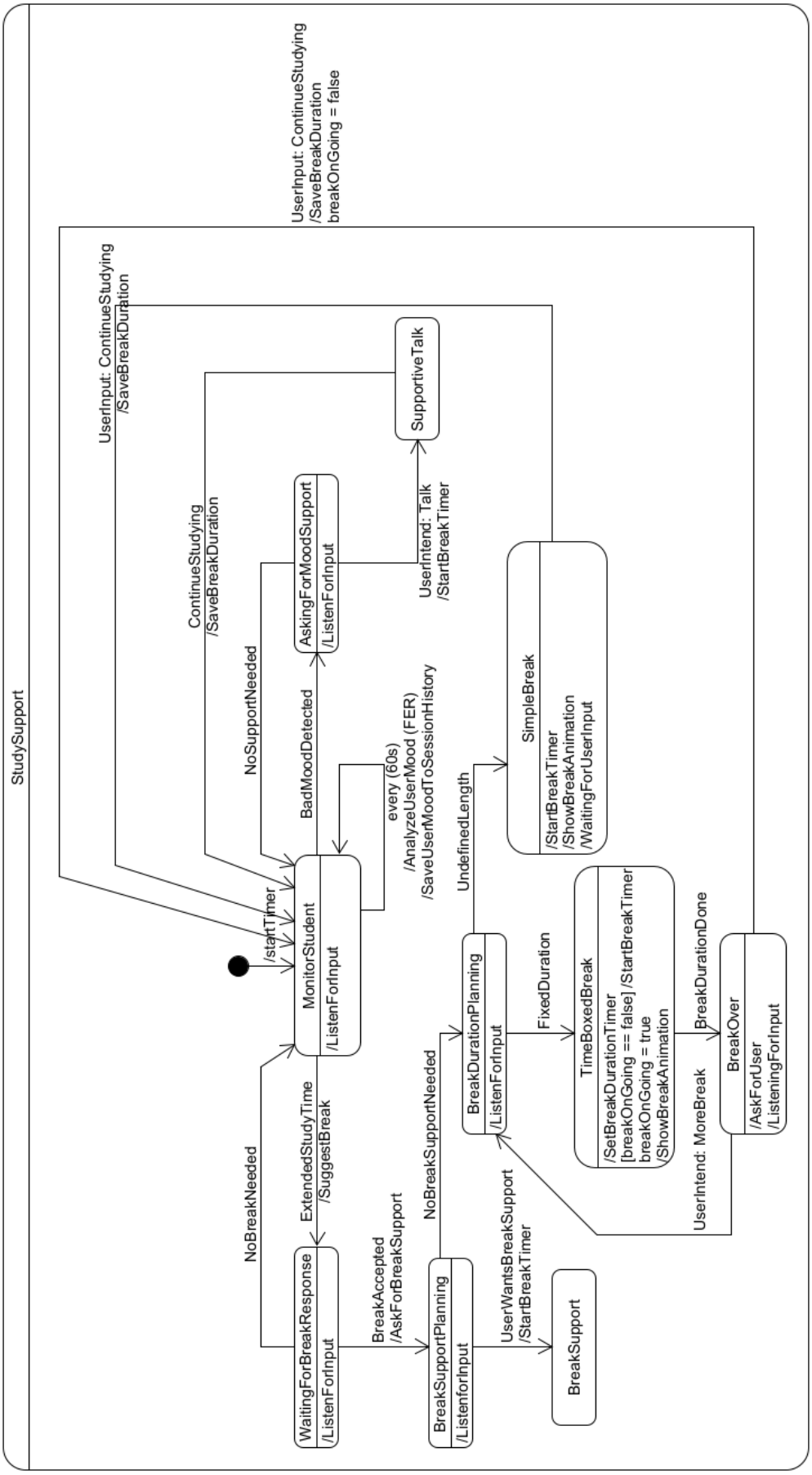
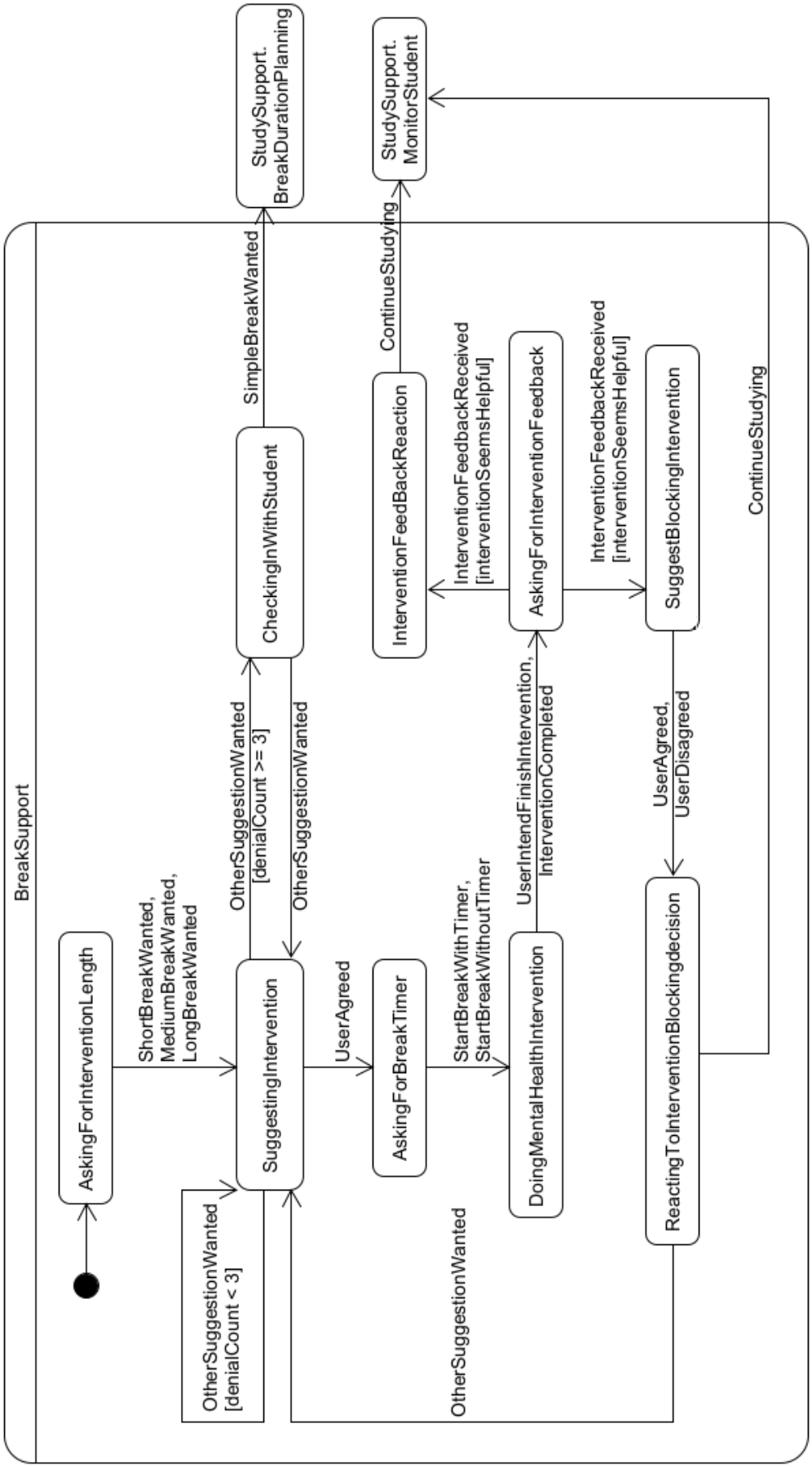
Appendix 2 Design diagram for the components of the mental health promoting companion app for students (with code)



Appendix 3 Inner design of the StudySupport state



Appendix 4 Inner design of the BreakSupport state



Appendix 5 Development Journey

As the author did not have any experience with mobile app development when she started with the implementation of the prototype, she first needed to learn the very basics of it.

Directly starting with cross-platform development, e.g. with the use of flutter seemed to complicate things, as she then would also have to test the app on both Android and iOS devices. Therefore, the decision to start with the implementation of just one operating system was quickly made.

Having the decision between Android and iOS it was an easy decision to begin with developing the prototype for Android-based devices. This was mainly because Android's market share is more than twice as big as the one from iOS [9] and secondly, because in general, Android-devices are cheaper in procurement – making the app more accessible for students, which usually don't have high financial resources to buy expensive smartphones [4]. So, with the goal of producing maximum value at minimum costs with the prototype, it was clear that developing a native Android app is the preferable way.

After having made the decision to develop the app natively for Android, the author first needed to gain some general knowledge about android app development with Kotlin. She did so by going through the official android development courses [1] and with the help of free tutorials posted on YouTube[18]. Finally, GPT-4o by open.ai [5] was utilized as a supplementary knowledge source to address challenges encountered in the implementation process. After having gained initial insights on Android-app-development, this significantly accelerated the development process compared to traditional methods, where developers typically consult multiple forums and documentation to find solutions [6]. Nonetheless, there were occasions when these conventional approaches were indispensable, either because the LLM could not address certain issues or up-to-date knowledge was required.

Going through the process of collecting all the information necessary to put the most important parts of the concept into practice, the author learned step by step to implement the app as designed. Wherever possible, she tried to apply best-practice concepts, such as the MVVM-pattern[19] for separation of concerns, clean-code approaches and the use of state of

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[18] Although it might be unconventional, the author wants to say a special "thank you" to Philipp Lackner, from which she learned most of the basics of native Android development. His Youtube-Channel [7] is highly recommended for anybody eager to learn Android.

[19] MVVM (Model View ViewModel) pattern: Architectural pattern to separate data presentation logic (UI or "View") from the business logic of the application, that overcomes the drawbacks of MVP (model-view-presenter) and MVC (model-view-controller) pattern. Consists of a model abstracting the data sources, which works together with the viewmodel, that contains business logic and works as a link between model and view. It also exposes state to the view. The view observes the viewmodels state and delegates user's actions to the viewmodel to be processed. [8].

the art frameworks such as Jetpack Compose for screen layouts, Dagger Hilt for dependency injection and of course, coroutines and flows: Two Kotlin-inherent language features that make a developer's life much easier (but sometimes also more complicated, when it comes to testing).

A flow can be imagined as a kind of stream, that transports data from one place to another, in an asynchronous publisher/subscriber style. Like the flow of water from a tap, the flow just starts flowing when somebody opens the tap. With respect to the Kotlin flow this means, it only starts emitting values, when on the other hand someone collects them. [3]

Coroutines on the other hand can be seen as Kotlin's lightweight answer to threads. Similarly, they are used for asynchronous task execution (e.g. for collecting flows in the background, while doing something else on the main thread), but they don't have the same overhead as a thread and therefore use less resources. [2]

Among other things, coroutines were used in the app, for loading and saving the user-profile, regular tasks like calling the emotion recognition API from Beyond Emotion or emitting mock emotions, for room-database-calls and for collecting the emitted flows.

There are many more android-specific aspects the author learned in the development of the prototype, but as this thesis is not about how to write native android applications, this should be enough for now, as the most interesting and important things one needs to know to understand the following paragraphs on architecture have been mentioned.

Sources:

[1] Google Developers. 2024. *Android Developer Courses* (2024). Retrieved April 10, 2025 from https://developer.android.com/courses/.

[2] JetBrains. 2024. *Coroutines are light-weight*: *Kotlin Language Documentation* (2024). Retrieved April 14, 2025 from https://kotlinlang.org/docs/coroutines-basics.html.

[3] JetBrains. 2025. *Flows are cold - Kotlin Documentation* (2025). Retrieved April 10, 2025 from https://kotlinlang.org/docs/flow.html.

[4] Netguru. 2023. *iPhone vs Android Users: Key Differences in Behavior and Preferences* (2023). Retrieved April 10, 2025 from https://www.netguru.com/blog/iphone-vs-android-users-differences.

[5] OpenAI. 2024. *ChatGPT* (2024). Retrieved April 14, 2025 from https://chatgpt.com/.

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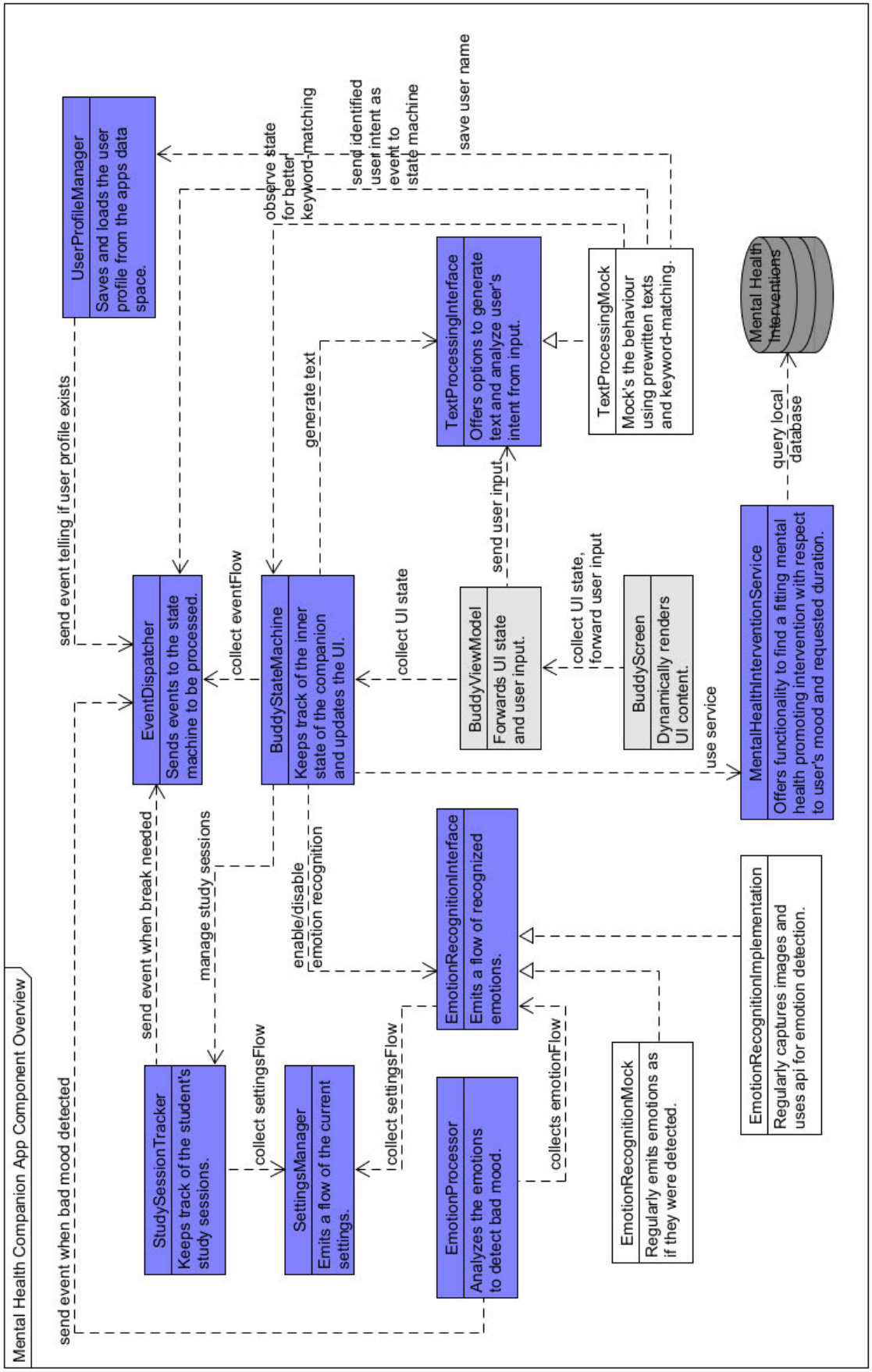
[8] Ashish Singh. 2023. *MVVM (Model View ViewModel) Architecture Pattern in Android*: *GeeksforGeeks* (2023). Retrieved April 10, 2025 from https://www.geeksforgeeks.org/mvvm-model-view-viewmodel-architecture-pattern-in-android/.

[9] Statista. 2024. *Global market share held by mobile operating systems 2009-2024*: *Statista* (2024). Retrieved April 14, 2025 from https://www.statista.com/statistics/272698/global-market-share-held-by-mobile-operating-systems-since-2009/.

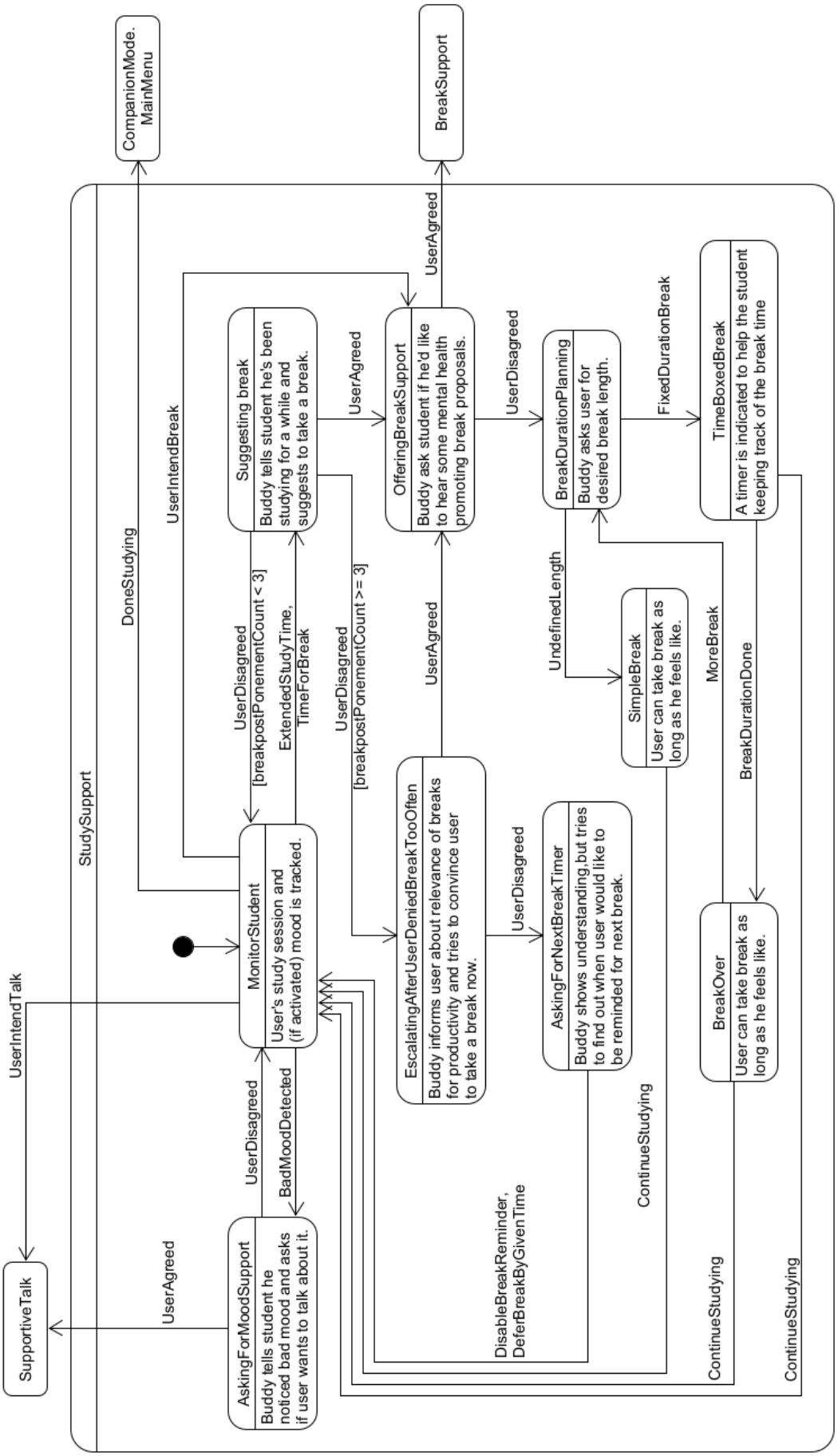
Appendix 6 List of all emotions that can be recognized by the Beyond Emotion API and their respective mapping

Emotion	Mapped Emotional State
Anger	Extremely Negative
Astonished	Surprised
Bored	Negative
Calm	Positive
Confused	Negative
Delight	Extremely Positive
Disgust	Negative
Fear	Extremely Negative
Happy	Extremely Positive
Laugh	Extremely Positive
Neutral	Neutral
Relaxed	Positive
Sad	Negative
Scream	Extremely Negative
Shock	Negative
Smile	Positive
Surprise	Surprised

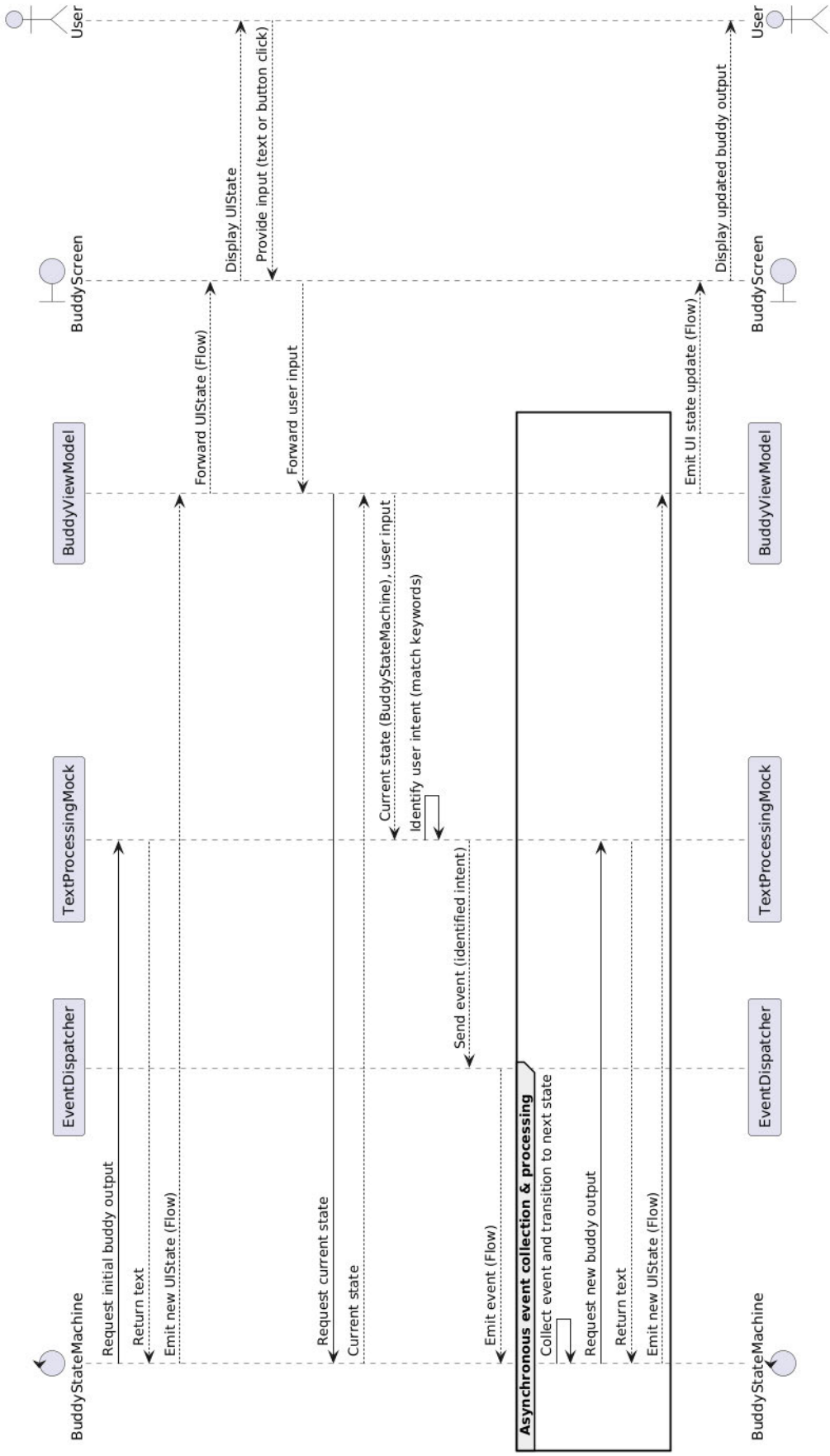
Appendix 7 Overview of the architecture of the implemented prototype



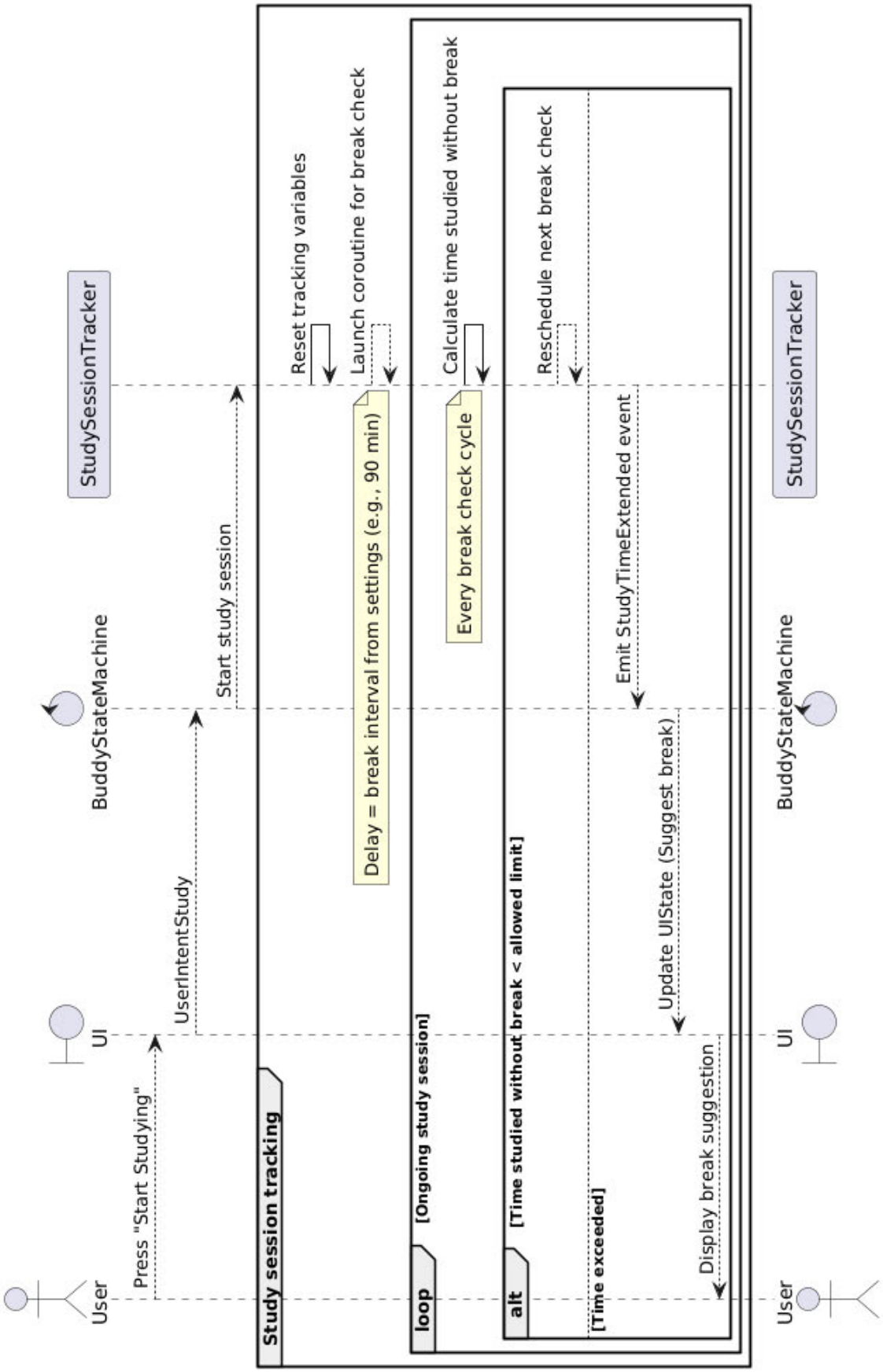
Appendix 8 Final inner design of the StudySupport state



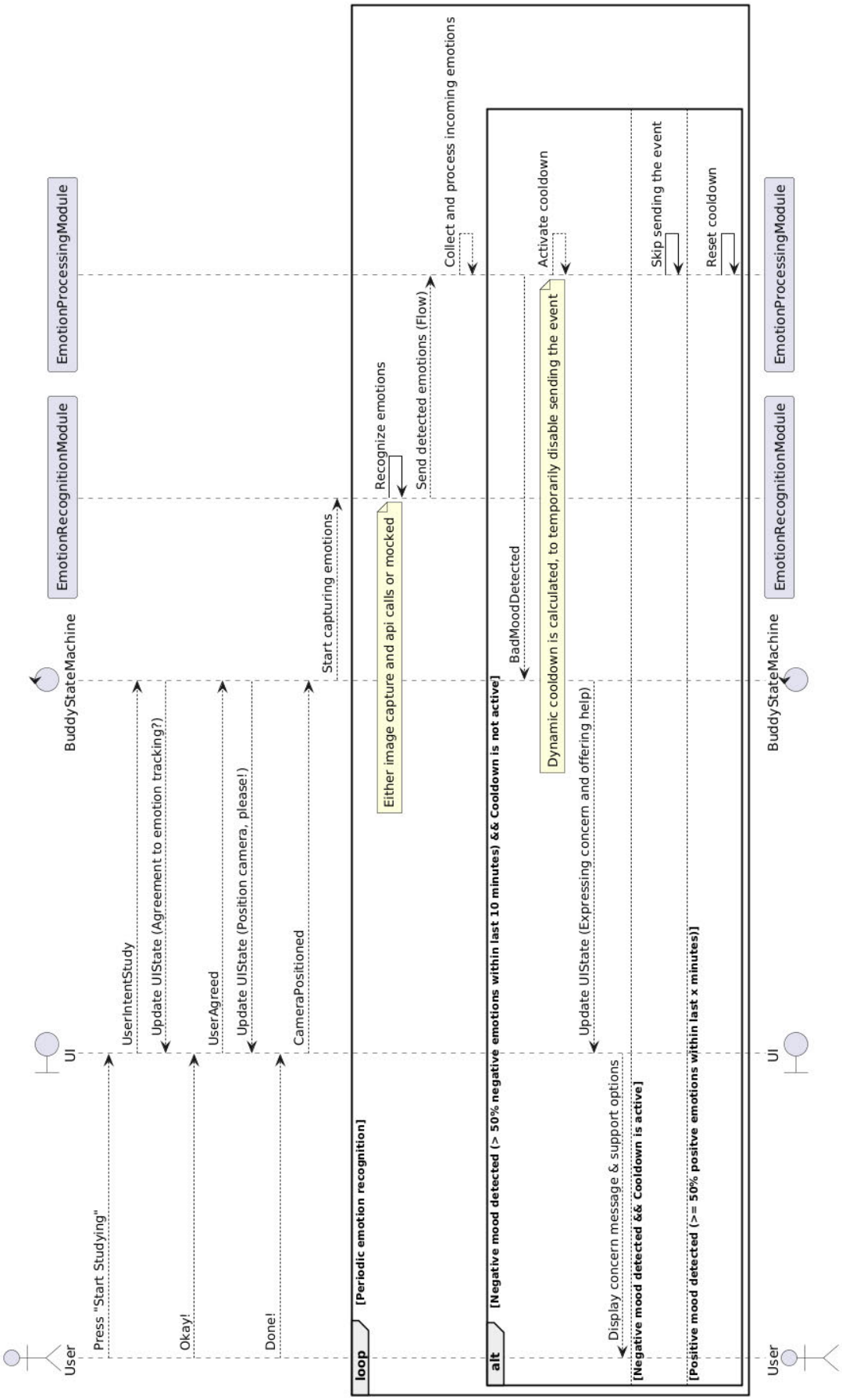
Appendix 9 Sequence diagram of the companion's output generation and user input processing



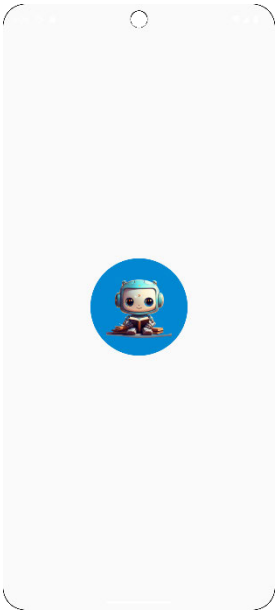
Appendix 10 Sequence diagram of study session tracking and break suggestion process



Appendix 11 Sequence diagram of the emotion monitoring and bad mood detection process

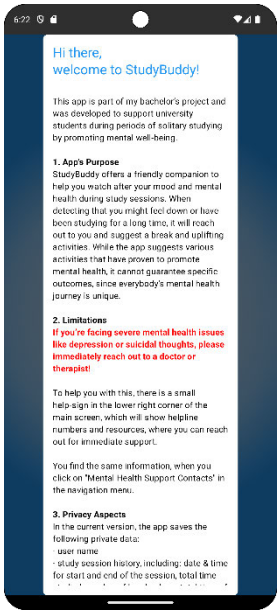


Appendix 12 Screenshots of the developed prototype

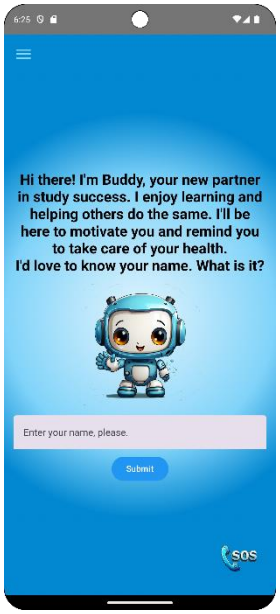


Screenshot 1: The app's logo (shown while device loads the application)

Screenshot 2: Splash - Screen (shown, while app checks for existing user data in the background)

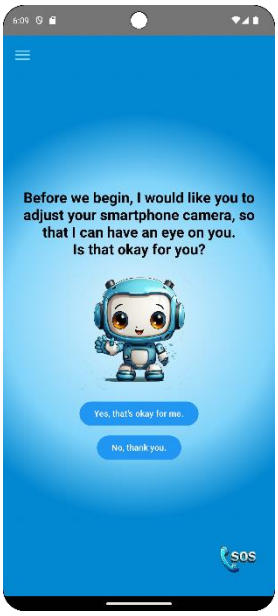


Screenshot 3: Disclaimer (shown on first app-start)



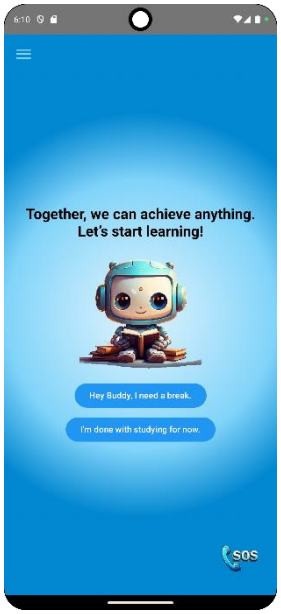
Screenshot 4: The companion introducing itself to a new user)

Screenshot 5: The companion greeting the user (CompanionMode.Mainmenu)



Screenshot 6: The companion asking the user to position their camera (CompanionMode.AskingForCameraPositioning)

Screenshot 7: Preview of the device's front camera, so that the user can position their device accordingly. (CompanionMode.PositionCamera)



Screenshot 8: Companion motivating the student while studying. (StudySupport.MonitorStudent)

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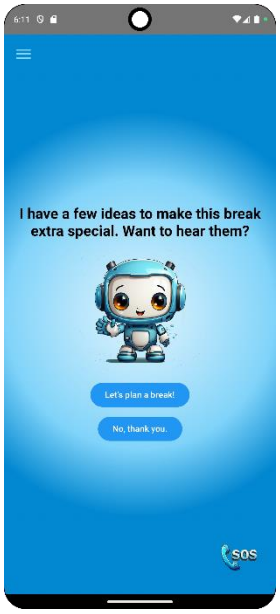
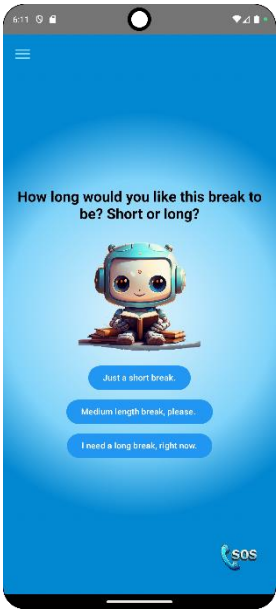
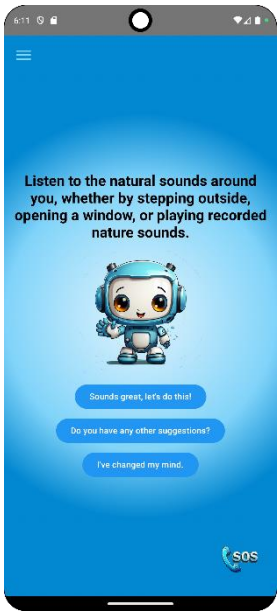


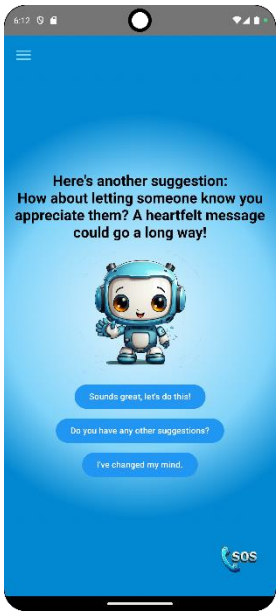
Screenshot 9: Companion asking the user if they want ideas how to promote mental health during the break. (StudySupport.AskingForBreakSupport)



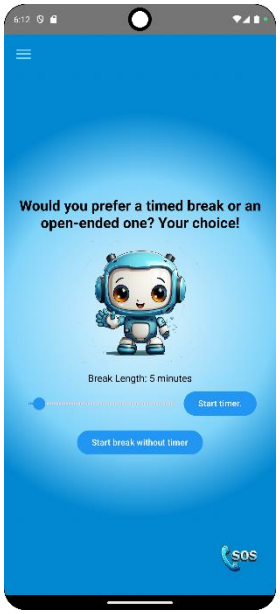
Screenshot 10: Companion asking user for desired length of the intervention (BreakSupport.AskingForInterventionLength)



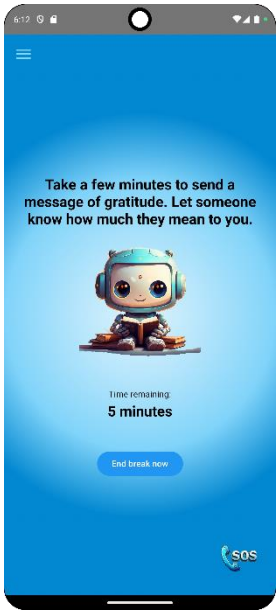
Screenshot 11: Companion suggesting a mental health promoting break activity (BreakSupport.SuggestingIntervention)



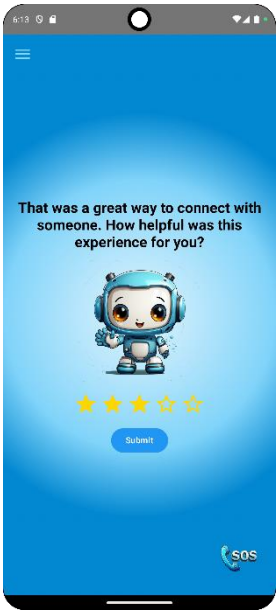
Screenshot 12: Companion suggesting another intervention, after user denied the first one. (CompanionMode.SuggestingIntervention)



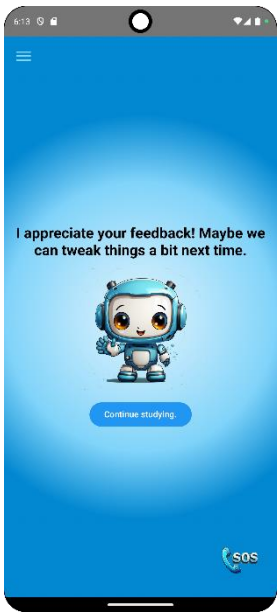
Screenshot 13: Companion asking the user, if they want it to set a break timer (BreakSupport.AskingForBreakTimer)



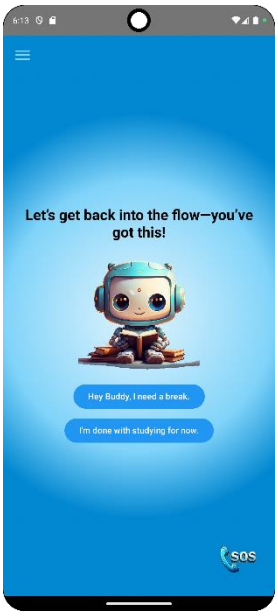
Screenshot 14: Companion instructing the user what to do during the mental health promoting break,. (BreakSupport.DoingMentalHealthIntervention)



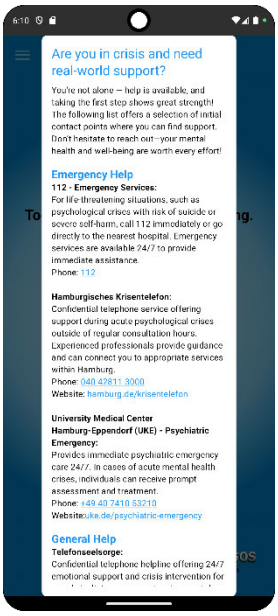
Screenshot 15: Companion asking the student for a feedback on the intervention. (BreakSupport.AskingForInterventionFeedback)



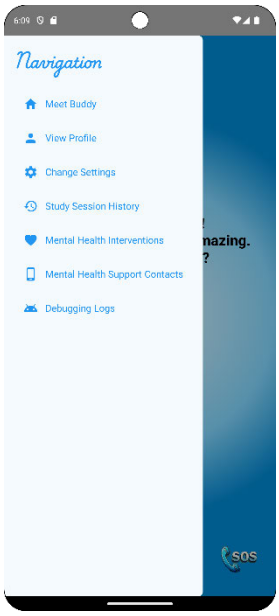
Screenshot 16: Companion reating to the user's feedback given. (BreakSupport.InterventionFeedbackReaction)



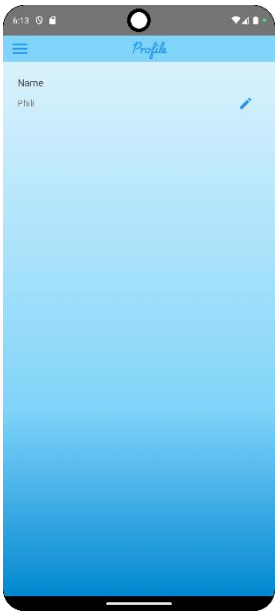
Screenshot 17: Companion motivating the student during study session after a break. (StudySupport.MonitorStudent)



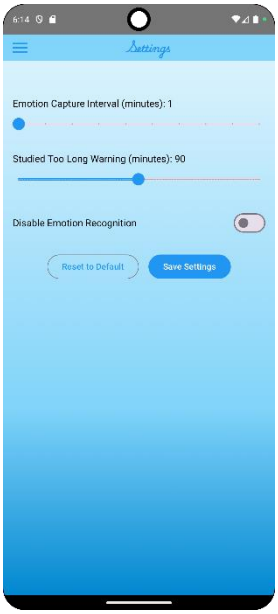
Screenshot 18: Mental health contacts information (opens, when user clicks on "SOS"-sign in lower right corner)



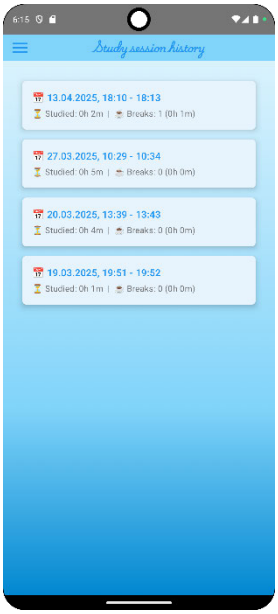
Screenshot 19: Navigation panel (opens, when user clicks on the burger menu icon in the upper left corner)



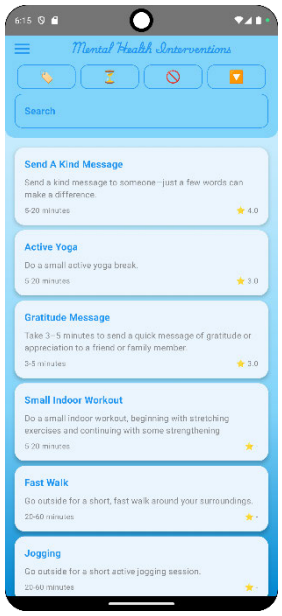
Screenshot 20: User profile screen (reachable through the navigation panel)



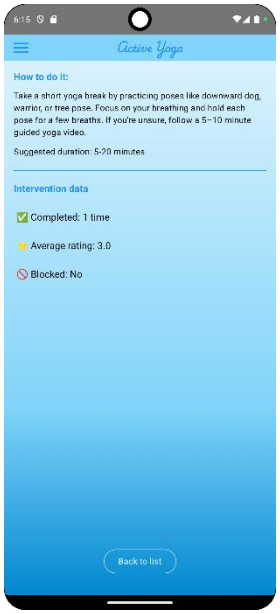
Screenshot 21: Settings screen (reachable through the navigation pane)



Screenshot 22: Study session history screen (reachable through navigation pane)



Screenshot 23: Mental health interventions list (reachable through navigation pane)



Screenshot 24: Mental health intervention details screen (reachable by clicking on any item in the mental health interventions list)

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Appendix 13 Full list of sample texts used in the developed prototype

1. The companion's self-introduction

- "Hi there! I'm Buddy, your new study companion. I love learning new things and helping others stay focused and motivated. I'll be here to not only assist you with your studies but also to make sure you're taking care of your mental health."
- "Hello! I'm Buddy, and I'm excited to be your study partner. I have a passion for education and well-being, so I'll be here to support you both in your studies and in maintaining a healthy balance."
- "Hey! I'm Buddy, your friendly assistant. I enjoy exploring different subjects and I'm a big advocate for mental health. Together, we'll make sure you stay on track and take necessary breaks."
- "Greetings! I'm Buddy, and I'm here to help you achieve your study goals. I love diving into new topics and I'm committed to helping you manage your stress and stay motivated."
- "Hi! I'm Buddy, ready to be your study partner. I believe in the importance of a balanced life, so I'll be here to remind you to take breaks and keep your mind and body healthy."
- "Hello! I'm Buddy, your personal guide to effective studying. I have a knack for keeping things organized and I'm here to support you in both your academic journey and your well-being."
- "Hey! I'm Buddy, here to make your study sessions more productive. I love helping students find the best ways to learn and I'll also be here to ensure you're looking after yourself."
- "Hi there! I'm Buddy, your new partner in study success. I enjoy learning and helping others do the same. I'll be here to motivate you and remind you to take care of your health."
- "Hello! I'm Buddy, your assistant to keep you motivated and focused. I believe in the power of a healthy mind and body, so I'll be here to support you in your studies and your overall well-being."
- "Hey! I'm Buddy, looking forward to helping you with your studies. I have a passion for education and mental health, so I'll be here to ensure you stay on track and take necessary breaks to stay healthy."

- Asking for the user's name

- "What's your name?"
- "Can you tell me your name?"
- "I'd love to know your name. What is it?"
- "Let's start with your name. What should I call you?"
- "What's your name, friend?"
- "May I have your name, please?"
- "To get to know you better, what's your name?"

- Greeting the user

- "Good morning"
- "Good afternoon"
- "Good evening"
- "Hey"
- "Hi"
- "Hello"
- "Nice to see you"
- "Welcome back"
- "Good to see you"

- **Motivating the user to start studying**
- "Are you ready to start studying?"
- "Ready to tackle your goals?"
- "Let’s make today great."
- "How can I support you today?"
- "Let’s achieve something amazing. What’s on your mind?"

- **Asking the user for agreement for facial emotion recognition**
- "Before we begin, I would like you to adjust your smartphone camera, so that I can have an eye on you. Is that okay for you?"

- **Asking the user to position the device for emotion recognition**
- "Please position the camera so I can see your face clearly."
- "Could you please adjust the camera position so your face is fully visible?"
- "Please make sure the camera is positioned to capture your face clearly."
- "Let’s adjust the camera position so I can see your face."
- "Can you position the camera, so that it captures you face, please?"
- "Let’s ensure the camera position captures your face perfectly."
- "Please make sure the camera is in a good spot so I can keep an eye on you."
- "Let’s find the right position so I can see you comfortably."
- "Please take a moment to set up the camera so I can see you clearly."
- "Let’s make sure everything is set up so I can keep you in sight."

- **Study motivation in beginning a study session**
- "Let's dive into learning together — I've got your back!"
- "Ready to conquer this study session? I’m right here with you."
- "We’re a team! Let’s make progress, one step at a time."
- "You're not alone—let’s tackle this and learn together!"
- "I’m here to support you every step of the way. Let’s do this!"
- "Together, we can achieve anything. Let’s start learning!"
- "I’ll keep an eye on things while we dive into these books."
- "We’ve got this! I’m here to help whenever you need it."
- "Let’s make this session productive and fun—together!"
- "With me by your side, you’re unstoppable. Let’s begin!"

- **Study motivation after returning from a break**
- "Welcome back! Let’s pick up where we left off and keep the momentum going!"
- "Break’s over—let’s dive back in and finish strong!"
- "Feeling refreshed? Let’s get back to studying and make great progress!"
- "I’m glad you’re back! Ready to keep going? Let’s do this together!"
- "You’re doing great! Let’s jump back in and tackle the next part."
- "Time to refocus! I’m here to help you stay on track."
- "Let’s get back into the flow—you’ve got this!"
- "Welcome back! Let’s turn that fresh energy into solid progress."
- "Let’s continue where we left off. Every step counts!"
- "You're back and ready to go—let’s make the most of this session!"

- **Checking in with user after negative mood has been detected**
- "You seem a bit down. Would you like to talk about what's on your mind?"
- "I'm here if you feel like sharing how you're feeling. Do you want to talk?"
- "It seems like something might be bothering you. I'm here to listen if you'd like to chat."
- Hey, I noticed you might not be feeling your best. Would you like to share what's going on?"
- "If something's weighing on you, I'm here for you. Do you feel like talking?"
- "You don't seem quite yourself today. Want to tell me what's up?"
- "I'm here to help if something's on your mind. Do you want to talk about it?"
- It's okay to have tough days. I'm here to listen if you need to vent."
- "You seem a little off today. Would talking about it help?"
- "Whatever you're feeling, I'm here for you. Do you want to share how you're doing?"

- **Proposing a break**
- "You've been studying for quite some time. How about taking a well-deserved break?"
- "It's important to take breaks to recharge. Would you like to step away for a bit?"
- "Your brain works best when it gets some rest. How about a break now?"
- "You've done a great job so far! Let's take a short break to refresh your mind."
- "Breaks are key to staying productive. Do you want to pause for a moment?"
- "I noticed you've been at it for a while. How about taking some time to relax?"
- "Even short breaks can boost your focus. Ready for one?"
- "Don't forget: rest is as important as work. How about a break now?"
- "Let's step away for a moment. A break could do wonders for your focus!"
- "Taking care of yourself includes breaks. How about one now?"

- **Reacting to a break denial**
- "Got it! Let's keep going—you're doing great."
- "Alright, no break for now. I'm here to keep you on track!"
- "Understood! Let's focus and make progress together."
- "Okay! Let's keep up the momentum and push forward."
- "No problem! I'm here to support you however you need."
- "Alright! Let's make the most of this study session."
- "I hear you! Let's keep moving ahead and stay productive."
- "Okay, let's keep going. I know you've got this!"
- "Alright, no break! Let's dive back in and make progress."
- "Got it! I'm right here with you—let's keep learning!"

- **Soft nudging, when user denied to take a break several times**
- "Alright, I see you're really in the flow right now. I just want to make sure you're not over-working yourself. When do you think you'll be ready for a break? Should I remind you in a bit?"
- "I get it—you're deep in focus, and I respect that! Just promise me you won't forget to rest. When should I check back to see if you're ready for a short break?"
- "I understand—you want to keep going! But please remember, even small breaks keep your energy up. When do you want me to remind you again?"
- "Okay, I won't push! I just care about your well-being and want to make sure you stay at your best. When do you think would be a good time to check in again?"

- "Understood! You're really committed, and I admire that. Just let me know—when should I remind you again for a break?"
- "I won't interrupt your flow, but I do want to make sure you're pacing yourself. When would be a good time for me to check in again?"
- "Got it! Just know that I'll be here when you're ready. Would you like me to remind you again in a little while?"
- "I see you're fully focused, and that's awesome! Just keep in mind that a little break might help later. When should I nudge you again?"
- "Alright, I respect your focus! But if you push too long, your mind might start slowing down. When do you think would be the best time for your next break?"
- "No worries! I trust that you know what you need. Just let me know—should I check in again in a few minutes?"

- **Break reminder, after user set a timer for next break reminder**
- "Ding! That's your cue! You told me to remind you, and here I am. Let's take that break now, okay?"
- "Alright, time's up! We agreed you'd take a break around now — let's follow through and make it happen!"
- "Hey, I'm back — just like we talked about! Seems like a good time for that break, don't you think?"
- "Popping in as promised! We said I'd check in, and here I am. Ready to take that pause now?"
- "I know you're working hard, but I really want to make sure you're taking care of yourself too. How about that break now?"
- "I know you're deep in focus, but stepping away for a few minutes could really help. I care about you doing well *and* feeling well. Shall we?"
- "Hey, time flies! Just dropping in like we agreed — think now's a good moment for that break?"
- "Just checking in! A short pause now might help keep your energy up for the rest of the session. Want to take it?"
- "The moment has come! Your reminder is here, and you deserve this pause. Let's step away for a bit — shall we?"
- "Your reminder is here, and you know what? I think this is the perfect time to follow through. What do you say?"

- **Reacting, when user finally agreed to take a break**
- "Great choice!"
- "I'm so glad you're taking a break!"
- "Awesome, you deserve this!"
- "Nice! A little rest will do you good!"
- "Fantastic! Let's make the most of this break!"
- "Yes! Your brain will thank you!"
- "I'm happy to hear that!"
- "Good call! A short break will help a lot!"
- "Perfect! Time to recharge a bit!"
- "Awesome! Let's step away for a moment!"

- **Reacting, when user consecutively denied to take a break**
- "I love your determination, but skipping breaks too often can lead to fatigue and slower progress. Even five minutes can refresh your mind!"

- "Being in the flow is great, but your brain also needs rest to process information better. Just a short reset could keep you sharp!"
- "I get it—you want to keep going. But pushing too hard for too long actually reduces efficiency. A quick reset might keep your momentum going longer!"
- "Your energy is impressive! Just don't forget that our brains consolidate learning during breaks. Even a quick one could make all this effort stick better!"
- "Taking breaks isn't slacking — it's strategy. A small pause now could help you finish even stronger!"
- "Even a short break can give your brain the reset it needs to keep performing at its best. Want to give it a try?"
- "Pushing through is great, but smart breaks actually help you work better for longer. A quick pause might help you keep this momentum up!"
- "Research shows that short breaks improve memory and focus. A few minutes away from work now could help you study even more effectively!"
- "I know you're focused, and that's great! Just remember that stepping away for a moment can prevent burnout and keep you at your best."
- "Your mind works hard — giving it a short breather could help you return even stronger. Want to give it a shot?"

- **Reacting to the user's decision to disable break reminders**
- "Alright, I'll respect that. I'm still here to support you—let's make this session great!"
- "Got it! No more break reminders. Let's focus and make the most of this study time."
- "I hear you! Just know I'm still here to help. Let's keep up the good work!"
- "Okay, I won't bring up breaks again. You've got this, and I'm right here with you!"
- "Understood! Let's push through together—I'll be here if you need anything."
- "Noted! I won't interrupt again. Let's stay focused and finish strong!"
- "Alright, I won't nudge you about breaks. Let's keep going—I believe in you!"
- "Got it! I'll step back on break reminders, but I'm still here for anything else."
- "Okay, I trust your judgment. Let's keep up the momentum and make progress!"
- "No problem! I'm here to support you however you need—let's keep moving forward!"

- **Reacting to an accepted break**
- "Would you like some support during your break? I have ideas to make it refreshing!"
- "Breaks can be rejuvenating. Can I suggest activities for your break?"
- "How about making this break extra helpful? I can suggest some ideas."
- "Let me help make your break meaningful. Would you like suggestions?"
- "I can guide you through some relaxing or uplifting activities. Interested?"
- "Would you like to try some activities that can promote your mental health during this break?"
- "Breaks can be more than just rest. Let me suggest some supportive activities!"
- "I have a few ideas to make this break extra special. Want to hear them?"
- "Let me suggest some break activities tailored just for you. Would you like that?"
- "Would you like me to recommend some relaxing or energizing activities for this break?"
- **Asking for break length, when user does not want to do an intervention**
- "Would you like to set a timer for this break, or just start and go with the flow?"
- "Would you prefer a timed break or an open-ended one? Your choice!"
- "Do you want me to set a timer for this break, or would you rather take it freely?"
- "Let's decide how you'd like to take this break—should I set a timer, or would you rather keep it flexible?"

- "Would a timer help you stay on track, or would you like to take this break without one?"
- "I can set a timer for you if you'd like, or you can just enjoy this break at your own pace."
- "Would you like a set time for your break, or do you prefer to return whenever you're ready?"
- "Shall I set a timer to gently remind you when the break is over, or would you rather take it naturally?"
- "Would a time limit help you feel more structured, or do you want to take this break freely?"
- "Let me know if you'd like a timer for this break, or if you'd rather go without one!"

- **Friendly words, when a break (no intervention, no predefined length) starts**
- "Enjoy your break! I'll be here when you're ready to continue."
- "Have a wonderful and recharging break. I'm looking forward to when you return!"
- "Take this time to relax and refresh. I'll be here for you after your break."
- "Enjoy your break! Remember to recharge and take care of yourself."
- "This is your time to unwind. I'll be here when you're ready to get back to it."
- "Have a great break! Rest up and let's tackle more together later."
- "Use this time to relax and clear your mind. I'm excited to see you again soon!"
- "Enjoy your well-deserved break. Let's make the next session even more productive."
- "Take your time to recharge. I'm looking forward to seeing you refreshed!"
- "Have a lovely break! Remember, taking care of yourself is the best strategy."

- **Friendly words, when a break (no intervention, predefined length) starts**
- "Enjoy your break! I'll be here when you're back."
- "Take a refreshing break! Let's continue when you're ready."
- "Rest up and recharge. I'll be here for you when you return!"
- "Enjoy your break! I'll check in with you once you're back."
- "Take this time to relax. Let's pick up again when you're ready."
- "Have a great break! I'm looking forward to continuing with you afterward."
- "I hope your break is refreshing. Let's reconnect when you return."
- "Enjoy this pause. I'll be ready to help as soon as you're back."
- "Take your break, and we'll pick up where we left off once you're ready."
- "Relax and recharge. I'll be here when you're back."

- **Telling user that the timer set for break is over**
- "The break time is up. Are you ready to get back to studying?"
- "It's time to wrap up the break. Shall we dive back into your studies?"
- "The break is over. Are you ready to continue your session?"
- "Time's up for the break! Let's get back to work—are you ready?"
- "Your break has ended. How about we get started again?"
- "That's it for the break. Shall we get back to your study session?"
- "Time to transition back to studying. Let's tackle this together!"
- "The break is done. Are you ready to continue your progress?"
- "The timer's up. Let's dive back in — are you ready?"
- "Break's over! Shall we pick up where we left off?"

- **Asking for desired intervention-supported break**

- "How long would you like this break to be? Short or long?"
- "Let's plan your break time. How much rest do you feel you need?"
- "How long would you like to step away? Take your pick!"
- "Let's decide how much time you'd like for this break. Any preferences?"
- "What break duration feels right for you right now? I'm here to help plan it."
- "Would you like to set a specific duration for your break, or keep it open-ended?"
- "Let's find the perfect length for your break. Any specific duration in mind?"
- "How much time do you need to recharge? Let me know!"
- "Do you have a duration in mind, or should we keep it flexible?"
- "Let me know what feels best for you in terms of break length."

- **Reacting to positive (>= 4 stars) mental health intervention feedback**
- "I'm really glad that was helpful for you! Let's keep finding things that work well."
- "That's great to hear! I'm happy this made a difference."
- "Awesome! It's always good to have strategies that work for you."
- "I'm so glad that worked! Let me know if you ever want to try something similar."
- "That's exactly what I hoped for! Let's keep up the good momentum."

- **Reacting to neutral (3 stars) mental health intervention feedback**
- "Good to know! If you ever want to try a different approach, just let me know."
- "I appreciate your feedback! Maybe we can tweak things a bit next time."
- "Thanks for sharing! If there's anything that could make it better, I'd love to hear it."
- "That's fair! Let's see if we can find something even more useful next time."
- "Glad it was somewhat helpful! If you need a different option, I'm here to help."

- **Reacting to negative (<=2 stars) mental health intervention feedback**
- "I see, that wasn't quite what you needed. Let's try something else next time."
- "Thanks for letting me know! We'll keep searching for what works best for you."
- "I appreciate your honesty. Not everything works for everyone—let's explore other options."
- "That's okay, not every method is a perfect fit. Let's find something better together."
- "I understand. If there's anything specific you'd prefer, I'm happy to adjust."

- **Proposing to block an intervention, that has been rated negatively several times**
- "I've noticed this hasn't been helpful for you. Would you like me to stop suggesting it?"
- "Since this hasn't worked for you, would you prefer not to see it in future suggestions?"
- "I see this isn't quite your thing. Would you like me to remove it from future recommendations?"
- "It seems like this approach isn't a good fit. Do you want me to stop suggesting it?"
- "I want to suggest things that truly help you. Would you like me to exclude this one from now on?"

- **Reacting to the user's decision to block the intervention**
- "Understood! I won't suggest this one again."
- "Got it! This intervention is now off the list."
- "I'll remember that and won't bring it up anymore."
- "Alright, I won't recommend this again. Let's focus on what helps you best!"

- "Consider it done! I'll find better options next time."
- **Reacting to the user's decision not to block the intervention**
- "Sounds good! I'll keep this as an option for the future."
- "Alright, I'll still suggest it sometimes—just let me know if it ever changes!"
- "Got it! This intervention stays in rotation."
- "Okay! I'll keep this one in mind for you."
- "No worries! You can always skip it if it doesn't feel right."

Appendix 14 Disclaimer informing about the purpose and limitations of the developed prototype (textual content)

Hi there,

welcome to StudyBuddy!

This app is part of my bachelor's project and was developed to support university students during periods of solitary studying by promoting mental well-being.

1. App's Purpose

StudyBuddy offers a friendly companion to help you watch after your mood and mental health during study sessions. When detecting that you might feel down or have been studying for a long time, it will reach out to you and suggest a break and uplifting activities. While the app suggests various activities that have proven to promote mental health, it cannot guarantee specific outcomes, since everybody's mental health journey is unique.

2. Limitations

If you're facing severe mental health issues like depression or suicidal thoughts, please immediately reach out to a doctor or therapist!

To help you with this, there is a small help-sign in the lower right corner of the main screen, which will show helpline numbers and resources, where you can reach out for immediate support.

You find the same information when you click on "Mental Health Support Contacts" in the navigation menu.

3. Privacy Aspects

In the current version, the app saves the following private data:

- User name
- Study session history, including: date & time for start and end of the session, total time studied, number of breaks done, total time of breaks
- Ratings for mental health interventions, times repeated each intervention, last time each intervention was done

All data is kept on your phone and cannot be accessed by any third party. (As long as you don't provide unauthorized access to your phone[20])

4. Feedback & Contributions

Since StudyBuddy is still in development, your feedback would mean a lot! If you have suggestions, encounter issues, or want to contribute, contact me via: philine.pommerencke@haw-hamburg.de

[20] This disclaimer was written for the functioning of the application with the mocked emotion recognition. As the emotion recognition API was only utilized for initial system tests conducted by the author herself as user, the wording here was not adjusted.

Appendix 15 Overview of mental health contacts

Mental Health Support Contacts

Are you in crisis and need real-world support?

You're not alone — help is available, and taking the first step shows great strength!
The following list offers a selection of initial contact points where you can find support.
Don't hesitate to reach out — your mental health and well-being are worth every effort!

Emergency Help

112 – Emergency Services
For life-threatening situations, such as psychological crises with risk of suicide or severe self-harm, call **112** immediately or go directly to the nearest hospital. Emergency services are available 24/7 to provide immediate assistance.
📞 Phone: **112**

Hamburgisches Krisentelefon
Confidential telephone service offering support during acute psychological crises outside of regular consultation hours. Experienced professionals provide guidance and can connect you to appropriate services within Hamburg.
📞 Phone: **040 42811 3000**
🔗 Website: hamburg.de/krisentelefon

University Medical Center Hamburg-Eppendorf (UKE) – Psychiatric Emergency
Provides immediate psychiatric emergency care 24/7. In cases of acute mental health crises, individuals can receive prompt assessment and treatment.
📞 Phone: **+49 40 7410 53210**
🔗 Website: uke.de/psychiatric-emergency

General Help

Telefonseelsorge
Confidential telephone helpline offering 24/7 emotional support and crisis intervention for people in distress or experiencing mental health challenges.
📞 Phone: **0800 111 0 111**
🔗 Website: telefonseelsorge.de

Mental Health First Aid (HAW Hamburg)
Confidential support service for students at HAW Hamburg providing compassionate help for individuals in mental health crises and connecting them with professional resources when needed.
🔗 Website: haw-hamburg.de

116117 – Medical On-Call Service
Confidential helpline offering support for all health-related concerns, including assistance in psychological crises. They also provide a convenient service for scheduling initial appointments with psychotherapists.
📞 Phone: **116 117**
🔗 Website: 116117.de
ℹ️ Psychotherapist Appointment Service: eterminservice.de

Appendix 16 Overview of the test cases for the single components

EmotionProcessingModule:

- Correct detection of bad mood in the user, when mood is bad
- Correct detection of good mood in the user, when mood is good
- Cooldown-functionality of sending the BadMoodDetected event works as intended (the event is not spammed, when detected multiple times in a row)
- Resetting the cooldown after having identified an improvement in user's mood work as intended

StudySessionTracker:

- Study session saves the time correctly, when being started and stopped.
- Breaks are tracked correctly
- Tracking of multiple session works correctly
- Break proposal event is triggered as intended, after maximum study time has been reached
- Study session is only saved, if it aligns with the minimum duration defined[21]
- Break proposal is triggered correctly after user took a break on their own initiative before maximum study time has been reached
- Escalation is triggered correctly, after user postponed a break for three times
- Module reacts to setting changes and escalates, when next break proposal time would be too short

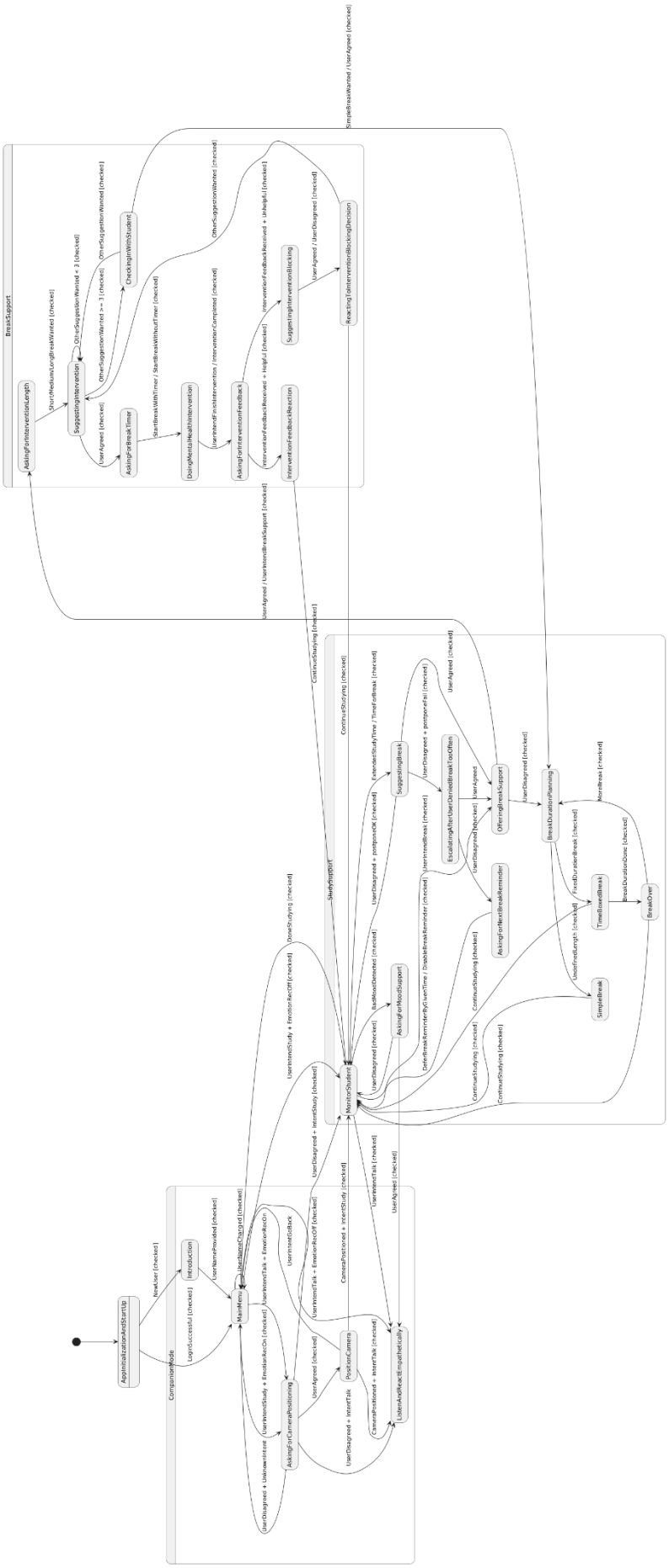
MentalHealthInterventionService:

- Finding a suitable intervention, in terms of type, duration and user's emotion (if provided)
- Returning null, if no suitable intervention has been found[22]
- Updating the intervention rating
- Updating the intervention blocking status

[21] This was not part of the requirements, but resulted in being very useful during system tests, as without this restriction, when clicking through the app, several very short study sessions were unnecessarily saved.

[22] This cannot happen within the developed prototype, as there are mental health interventions for any emotional condition of the user. Nevertheless, this test case seemed relevant to make sure the app does not unexpectedly fail, if no suitable intervention is found.

Appendix 17 Overview of the transitions tested within the BuddyStateMachine



Appendix 18 Examples of emotion recognition results from the API

Image captured[23]	Emotions recognized
	-
	ASTONISHED
	SHOCK, FEAR
	CONFUSED, DISGUST

[23] To preserve the author's privacy, the background of the images, which showed her personal space, has been extracted for this table. The results from the API as shown in the table are based on the raw images without any prior changes made.

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