Intelligent Agents that Support Students with Self-Study

Thomas Overklift

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by

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Abstract

University students are expected to study on their own for large amounts of time. However a lot of these hours are not spent effectively by students. Eventually students who have trouble with self-studying in an effective manner may end up failing courses because of this. When students realise they have a (self-study) problem they can seek aid by contacting the academic counsellor. However, there are problems with this workflow: students often need time to acknowledge they are having issues. Then, even when students contact the academic counsellor to get help, it is a difficult task to provide personalised support for each student.

In this thesis we investigate the feasibility of a *self-study support agent* that can assist students with feedback on their self-study behavior. This agent can support students next to the academic counsellors. An agent can continuously track students and provide immediate feedback, whereas counsellors have a limited amount of time available (per student).

As part of this thesis we conduct a focus group with academic counsellors, organise a workshop with first year students to create a design for a prototype self-study support agent. Thereafter we implement this prototype and use this in an experiment where the activities of several first year students are tracked over the period of two weeks. Then we analyse the data collected with our prototype agent. In doing so we show that the concept of the self-study support agent is feasible. We envision that future work can realise actual deployment of a self-study support agent.

Thesis Committee

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PREFACE

Over the course of my (many) years of studying and being a teaching assistant at the TU Delft, I've learned a lot about many things both in- and outside the domain of computer science. I would like to thank all of my friends, colleagues and the staff for making my stay in Delft a pleasant one, even during trying times. First of all, I would like to thank Myrthe Tielman for her continuous support during my thesis, and always being readily available to provide feedback and suggestions. I also want to thank her for assisting me with the required procedures for the approval of the Board of Ethics. I want to thank Catholijn Jonker and Birna van Riemsdijk for their input and helping me build this thesis around *agents* and *education*, which are two topics that really appeal to me. I am also really grateful to the academic counsellors that participated in the focus group and the students that spent time to participate in the workshop and use the activity tracker for the data collection experiment. Finally, I would like to thank my friends and family for supporting me and helping me finish this project on a good note.
I look forward to a long vacation and then returning to the TU Delft for another adventure.

Thomas Overklift
Delft, June 2019

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INTRODUCTION

University students are expected to study on their own for large amounts of time. For instance, Bachelor students Computer Science and Engineering are expected to self-study for approximately 18 hours per week [1]. However a lot of these hours are not spent effectively by students.

> *"Simply spending a lot of time studying is not enough, because that time can be spent very unproductively, but students cannot excel without both (a) studying effectively and (b) spending enough time doing so. Compounding the problem, it is difficult to monitor one's own study time because study sessions, even attending class, can include email, online shopping, social networks, YouTube, and so on."* [1]

Thus many hours are wasted by students on activities which are not actual studying, even though students conceive they are spending time studying. Eventually students who have trouble with self-studying in an effective manner may end up failing courses because of this. When students realise they have a (self-study) problem they can seek aid by contacting the academic counsellor. However, there are problems with this workflow: students often need time to acknowledge they are having issues. Next to that most students have to earn a minimum amount of credits in their first year in order to be able to continue their education programme. Then, even when students contact the academic counsellor to get help, it is a difficult task to provide personalised support for each student.

We hypothesise that an (intelligent) computer program or *agent* could support students with self-study next to the academic counsellors. An agent program has two benefits in comparison to academic counsellors: the agent could gather more information about students by continuously tracking their activity, and an agent could always be available to support students whereas counsellors have a limited amount of time available (per student). The usefulness of a *self-study support agent* relies on the data the agent needs and functionalities the agent offers. In this thesis we will investigate what kind of data and functionalities a self-study support agent needs to be useful, and how the agent should interact with counsellors and students. We will also address the privacy concerns related to the tracking of student activity and sharing of this information.

In the next section we will introduce several research questions which will structure our research into the requirements for a self-study support agent.

[1] https://www.tudelft.nl/en/education/programmes/bachelors/cse/bachelor-of-computer-science-and-engineering/degree-programme/

1.1. RESEARCH QUESTIONS

The scope of creating and testing a full fledged application of an agent with desirable behavior is too large for this thesis; therefore the scope of this project was limited to **researching the data and functionalities a self-study support agent requires from the perspective of both academic counsellor and first year students, and the implementation and validation of a proof of concept of such an agent**. This thesis project will be centred around the following questions:

Research Question 1: ***What are existing applications & techniques that can provide insight and help with study behavior?***
In order to create a new tool that supports students it first needs to be established which tools already exist and which functionalities they offer. The features embedded in these tools can be analysed to gain insight into which techniques or tools were used to date to assist users.

Research Question 1.1: ***What are existing applications that track computer activity?***
An important factor for the ultimate usefulness of the agent is the type and amount of data that the agent can reason about. There are many existing applications that tract the activity of a user on their computer. Many of these applications use different types of data for different goals.

Research Question 1.2: ***What are existing applications that support self-study?***
Students often struggle with self-studying in an effective manner, as they don't know how effective their methods are, and they struggle with self-reporting their progress. There are numerous applications available that aim to support students with their self-study methods and patterns. It should be investigated which of these techniques can be incorporated in a self-study support agent.

Research Question 2: ***What functionalities should a useful, privacy aware, self-study support system entail?***
This question is geared towards discovering the minimum set of features that an agent would require in order to support students with their self-study in some useful way, for instance by providing insight and feedback students did not have before. The interactions between students, counsellor and agent, the features the agent offers, as well as potential privacy constraints all need to be taken into account.

Research Question 2.1: ***What should the triangle of interactions between student, agent and counsellor look like?***
The agent will fulfil a new role in the interaction between the student and the academic counsellor. It requires research to establish what exact role the agent should fulfil in this new triangle.

Research Question 2.2: ***What functionalities does the agent require to fulfil its role in the triangle?***
Once it has been established what the exact role of the agent is within the triangle, it should be investigated what functionalities the agents requires in order to optimally fulfil its role.

Research Question 2.3: ***What data & knowledge does an agent need to successfully implement its functionalities?***
To properly function the agent will require a combination of raw data and domain knowledge (such as the goals of a user). Without either of these the agent will not be able to support the

user in a useful way, the agent will need to process the collected data an decide what to do based on the processed data and its knowledge.

Research Question 2.4: ***How can the privacy concerns that arise when student data is collected be addressed?***
In order to function optimally, the agent requires a vast amount of data to reason with. Some data is more privacy sensitive than other. It should be investigated which data can be safely collected, and which things should not be stored.

1.2. CHAPTER OVERVIEW

The remainder of this thesis is divided into seven more chapters. In chapter 2 we will look at research related to agents and the time management of students. Next to that we will discuss several relevant applications which currently exist in fields of activity tracking and self-study support. In chapter 3 we will summarise the results of an expert interview with several academic counsellors, whom we interviewed about their current activities related to students whom struggle, and their vision for an agent that could support both them and students in some way. Subsequently in chapter 4 we will describe the outcome of a workshop with several first year students. In this workshop we brainstormed about the possible functionalities of a self-study support agent together with the students, and we compared their input with the results from the interview with the academic counsellors. In chapter 5 we will explicate the structure of the prototype agent we created, which consists of three parts: an activity tracker which collects data from students, an agent which can analyse the activities of users and provide feedback, and lastly a connector which can parse data collected by the activity tracker and pass it to the agent. Then in chapter 6 we will discuss the results of an experiment where several students used the activity tracker for approximately two weeks. We will analyse the activities of the students with our Proof of Concept (PoC) agent and discuss information the PoC agent requires in order to provide feedback. In chapter 7 we will discuss the results of the experiment with the PoC agent and we will highlight the shortcomings along with several recommendations for future work. Finally in chapter 8 we will present our conclusion.

2

Related Work

To create an agent that is able to support students with useful advice several components are required. The agent needs information about the behavior of an individual student, and subsequently the agent needs reason about this data in order to provide support for this individual student based on the result of its reasoning.
For this thesis project previous work and tools that already exist for supporting people was investigated. Doing so various topics were covered; this will be discussed in this chapter. In section 2.1 different work on existing (intelligent) agents will be discussed. In section 2.2 several tools which exist for activity monitoring, and the functionality that they offer will be compared. After that, in section 2.3, different tools which serve to assist people with study related tasks will be analysed. Finally, in section 2.4, literature regarding support systems including *values* in such systems will be discussed.

2.1. Intelligent Agents

There are several definitions for artificial intelligence and agents; we will use the definition of Russell & Norvig to define (intelligent) agents in this thesis:

> *"We define AI [Artificial Intelligence] as the study of agents that receive percepts from the environment and perform actions. Each such agent implements a function that maps percept sequences to actions, and we cover different ways to represent these functions, ..."*[2]

Many different types of intelligent agents exist that aim to support people with different kinds of tasks, such as an *Intelligent Personal Assistant* that supports workers with planning and handling routine tasks more efficiently [3], or an *eHealth computer assistant* that supports people that are overweight with a more healthy lifestyle [4].

CoreSAEP is a computational reasoning framework for *Socially Adaptive Electronic Partners (SAEPs)* that can be applied to a multitude of different contexts, such as supporting disabled people with tasks in their daily lives that is being developed by the TU Delft [5, 6].

Creating a model for SAEPs is challenging because a SAEP should adhere to predefined societal norms, and adapt those norms over time. This is complex to model and reason about as there are multiple variables that can change over time. There is also an ethical aspect to the SAEP, since sensors and other data can be used as input for a SAEP privacy and security concerns may arise. This should already be accounted for in the design phase. Eventually people

should be able to use the SAEPs without having to change their lifestyle for the sake of using the SAEPs, and SAEPs should to be able to cope with changes and adapt to them appropriately. The CoreSAEP project currently has research efforts going into temporal logic and action hierarchies, to structure tasks and activities in a formal way that is usable for both the SAEP and the end user [7, 8]. In thesis we will construct a prototype agent that uses a similar structure to SAEPs, this will be discussed further in chapter 5.

2.2. Activity Monitoring Tools

An agent requires information about the applications an individual student is using and for how long that student is using each application in order to provide personalised feedback. There are many tools available today that aim to support people so that they work more effectively and gain insight in their productivity. Some of these tools are aimed at an individual person, while others are meant to be used by managers to monitor individuals. Since there already many tools that can monitor activities on a computer we aim to investigate whether we can incorporate one of these tools into our Proof of Concept (PoC) for a self-study support agent, rather than creating a new tool from scratch. The architecture of our PoC agent will be explicated in chapter 5.
In this section we will compare several existing activity tracking tools that can potentially be integrated into an agent that supports students.

2.2.1. Existing Activty Trackers

In this subsection we will discuss the functionality of several existing activity tracking tools. Since there are many different activity tracking tools available we will only review a portion of the tools available. We have attempted to select a diverse spectrum of popular tools ranging from large scale commercial solutions to non-commercial open source tools in order to compare the tools on various different levels.

RescueTime [9]

RescueTime is a commercial activity tracker targeted at consumers which offers a lot of functionality and supports Windows, Mac, Linux and Android. The tool provides a dashboard with an overview of which application you spent time on, and aggregates these statistics for longer periods of time. Each week, the user receives a report with their aggregated statistics, and allows them to set goals for next week. In this way the user can block certain apps or websites altogether or set a time goal. The app also offers automated tagging and categorisation for many applications and websites and is able to provide an estimated 'productivity score' in this manner.

Selfspy [10]

Selfspy is an open source activity tracker for Linux, OS X, and Windows based systems. Selfspy is command line based and allows for different commands to get specific data, such as computer usage, use of specific applications over a certain period of time, or an effectivity ratio for the user. The downside of this tool is that it has no GUI. There is no data visualisation apart from tables, and it requires some knowledge to use the program effectively.

ActivityWatch [11]

ActivityWatch is an open source activity tracker for Windows, Mac and Linux. The tracker offers optional tracking of websites and domains that are visited via a browser extension. ActivityWatch shows the user an overview of the applications they use the most, and has a timeline

overview. ActivityWatch also offers data exports in JSON[1] format.

ACTIV TRACK [12]

Activ Track is a commercial activity tracker targeted at employers that allows many customisation's for specific use cases. The tool works on Windows and Mac, and has support for the chrome browser on any OS. While this tool is not directly targeted at individuals, it does offer very detailed views and graphs, which show which apps are used and how often, the app has a time line overview and has custom rules that can allow for the usage of specific apps or sites for a limited amount of time before triggering a customisable action.

2.2.2. REQUIREMENTS FOR PROOF OF CONCEPT

There are several criteria which the tools introduced in the previous subsection should ideally meet, if they are to be useful for this project. Below is a list of criteria that are important for the tool to meet if it is to be used as a basis for this project.
The tool should:

- **be open source -** This is important because the tool should be adaptable for our specific purpose, and it should be verifiable what happens with the personal information that is collected regarding the users of the tool.
- **allow user access to own data -** Any individual student should be able to see what data is collected about him or her, and understand what is being shared. This is required by GDPR legislation [13].
- **be able to export data -** The data which is collected about individual students should be formatted in such a way that it can be used by the agent to reason about the activities which were monitored. If it is impossible to adapt the tool or export the data that is collected in a suitable format, the tool is not suited for our purposes.
- **have a suitable licence -** Since we may want to use the PoC agent that is developed in this thesis more extensively in the future, the tool that is being used to monitor the activities of students should ideally have a licence that allows use and adaption of the tool for non commercial purposes. If this is not the case we risk having to remove the tool from our agent at some point in the future.
- **have a GUI -** Since we want to use (an adapted version of) the tool to collect data for this project, it should be easy to use for users. They should be able to see what information the tool collects easily, and be enabled to make an informed decision on whether they want to share data with others, such as the academic counsellors.

Tool	Open Source	User Access	Allows Data Export	Suitable Licence	GUI
RescueTime [9]	✗	✓	▼ (paid only)	✗	✓
Selfspy [10]	✓	✓	✓	✓	✗
ActivityWatch [11]	✓	✓	✓	✓	✓
Activ Track [12]	✗	✗	✗	✗	✓

Table 2.1: Comparison between four activity monitoring tools.

[1] http://www.json.org/

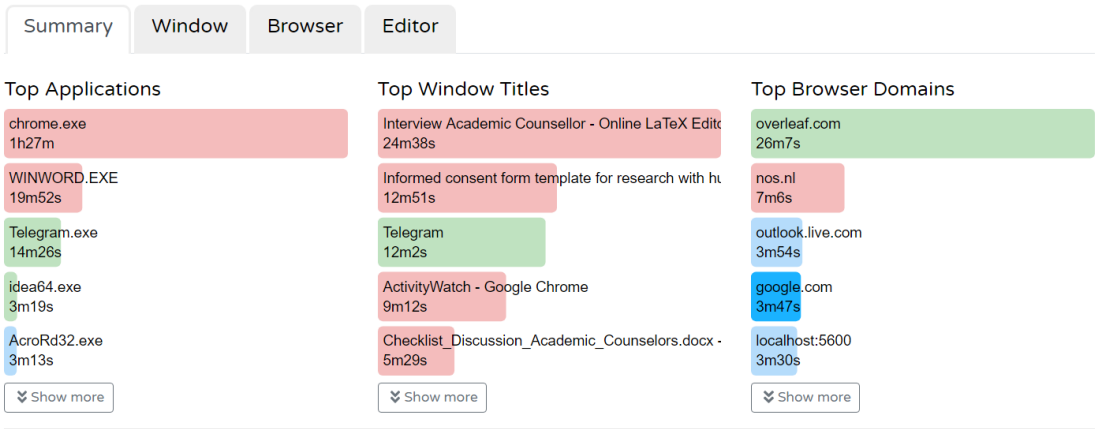

Figure 2.1: The dashboard ActivityWatch shows to it's users.

Table 2.1 shows a comparison between the leading tools that we introduced on the criteria defined above. It should be noted that one of the tools, Actriv Track [12], is focused on tracking employees for managers rather than self monitoring but was included in this comparison because it includes very detailed tracking information and overview dashboards. Unfortunately however, as can be seen in Table 2.1, this tool scores the worst when it comes to meeting the criteria that are important for this project. The tool that achieves the best results according to our criteria is ActivityWatch [11]. It is the only tool we analysed that meets all of the criteria we set. ActivityWatch is an open source tool that is licensed with the MPL-2.0. This tool offers tracking of both applications and in browser tabs, allows the user to see their own data in a dashboard, and supports data export in JSON format. Figure 2.1 shows an overview of the dashboard the user can view in ActivityWatch. Even though the data that is collected and displayed is not as extensive as with some of the other tools, ActivityWatch has information about which applications are used and for how long, which is the most important for this study. Since this tool is open source, it can be extended or adapted in the future, which is a great advantage over the commercial tools where this is either impossible or requires cooperation with the owner of the tool.
The tool can't be deployed as is though, since the data that is exported potentially contains personal information in application titles, or browser domains. This is why we propose to adapt the data that is exported so it does not reveal any personal details but merely statistics about how long each application is used. The incorporation of ActivityWatch in the PoC agent will be discussed further in chapter 5.

RQ 1.1 *What are existing applications that track computer activity?*

As discussed in section 2.2 there is an ample range of applications that track computer activity available, thus only a sample was analysed. All of the tools that we studied use the applications that the user has open and time metrics as a basis. However, apart from that there is a large difference between the characteristics of these applications. Some are focused on individual progress, whereas others focus on corporate productivity. Some only offer basic command line metrics, others provide a rich GUI. The applications that are most suited for self-study support are the applications that focus on individuals, value user privacy, offer comprehensible overviews and support multiple operating systems.

2.3. SUPPORT FOR STUDENTS

Next to the basic collection of data, another crucial part of a self-study support agent is how the agent will support students (and potentially the academic counsellor). Unlike the activity tracking tools which were compared in the previous section, sophisticated ways of providing feedback, or supporting users will not be part of the PoC we will create. However, we will look at several tools that support users (with self-study) in this section, as is this is relevant contextual information. There is a multitude of applications that support self-study available, therefore only a small number of apps was analysed. *Todait* is being discussed because it is the most popular free study support application available on both Android and iOS. *Ace your Self-Study!* & *NiceDay* are included in this list because their creators are cooperating with the TU Delft in different research projects.

TODAIT - SMART STUDY PLANNER

Todait is a commercial self-study application that is available for both Android and iOS devices, with over one million downloads [14]. Todait offers students the opportunity to set study goals, such as completing a certain amount of problems in a predefined amount of time, reminders, to do lists and helpful overviews. This way students can plan the work they need to do ahead of time and start study sessions to get the work done. The app relies on self-reporting by the user, so it cannot verify whether users enter (in)correct information. The paid version of the app furthermore offers personalised feedback on your study effort and the creation of study groups in which students can work towards their own study goals together as an additional form of motivation.

ACE YOUR SELF-STUDY!

Ace your Self-Study! is an application developed by the Erasmus University Rotterdam, in partnership with the Leiden University and the Delft University of Technology, to help students study and simultaneously provide input for research conducted by Martine Baars [15]. The app, which is available on both Android and iOS, allows users to create study sessions in which they specify what they will be studying (e.g. solving problems or writing for an assignment) and what strategy they will use. There are over twenty study strategies too choose from, distributed over several different study activities. The user can reflect on their study progress after they have completed a study session and rate the progress they made and the study strategy they used. All of this information is logged and allows users to review which strategies have worked for them in the past and which have not.

NiceDay

NiceDay is an application developed by Sense Health, available on both Android and iOS, that can help patients that suffer from depression, anxiety and stress [16]. This application is not directly related to students or studying, but is relevant in the context of combining the strengths of both human and agent interaction because it offers a unique concept: users can get direct help from medical professionals via the application. Our agent could offer similar functionality to accommodate communication between a student and an academic counsellor.
NiceDay offers several basic features: users can self report on how they are feeling throughout the day on a scale of one to five and can attach notes to each moment if they wish to; next to that users can create a diary and a conversation log book and add entries on their own. The app also offers users the opportunity to set tasks and goals for each day, so they can keep track of what they want to achieve, and improve their situation over time. Finally, and most importantly, users can contact a medical professional via the app; this can be done completely anonymous. This way users can start receiving professional help without the threshold of having to meet a therapist in real life. Receiving help from a therapist has several advantages. Users are able to get help "on demand": when they need help they can contact a therapist and can quickly start a video call or a chat. This requires flexibility from the therapists since this way of working is quite different. However, for a patient this method of getting professional support is much faster than the usual process, which requires creating an appointment at a therapists' office. Vice versa, the therapist can also contact the patient quickly when they think the patient could use some encouragement or has an important event coming up.

RQ 1.2 *What are existing applications that support self-study?*
As discussed in section 2.3 there are several applications that support self-study. The goal of the applications differs between applications from improving self-reporting, to testing different self-study methods motivating users to spend more time studying. However all apps feature short feedback cycles, where a user gets feedback after a study session or completing a report, this helps them improving their behavior.

2.4. Time and Stress Management

Next to the applications that are already available which were discussed in the previous subsection, there is a lot of research being done towards technological support for both students and professionals that require help with time and stress management. The need for such systems is illustrated by a resent study among students of the Hogeschool Windesheim which shows that 38,9% (1221) of the participants experience light to moderate stress and anxiety symptoms and 14,4% (453) students experience severe stress and anxiety symptoms ($n = 3134$) [17]. On top of that 68,9% of the students indicated to experience pressure to perform often to very often. Previous research also shows that there is a correlation between time management and experienced levels of stress, as students that feel in control of the situation experience lower levels of stress [18].

A proof of concept study by Anna Touloumakos et al. in which "an innovative online multimedia system supporting mood, wellbeing, study skills and everyday functioning of higher education students" (MePlusMe) was created and tested on higher education students, received positive feedback from participants [19]. When asked what kind of study skills the system

could support in a questionnaire, students indicated that they wanted: procrastination (73%), attention/concentration (62,5%) & time management (59%) to be supported most frequently ($n = 540$).

These studies show that there is definitely an area in which (smart) systems could aid students with managing their study workload and stay on top of the situation. This would in turn be beneficial to the levels of stress that students experience. A concept that is well known in this domain is that of behaviour change support systems (BCSS). Oinas-Kukkonen defines a BBCS as follows:

> "A behavior change support system (BCSS) is an information system designed to form, alter or reinforce attitudes, behaviours or an act of complying without using deception, coercion or inducements." [20]

This fits the goal of our agent, which is to help a student study more effectively, mainly by providing them with more structure so they can improve their behaviour. The agent should help the student get in to the habit of studying in a frequent and effective manner.

EXISTING SUPPORT SYSTEMS

A recent review of web-based support systems for students in higher education shows that there are already several support systems that specifically target students in development [21]. The researchers identified six systems that were in development during their study that were specifically aimed at students of higher education. Only two of these systems were online during the time of this literature survey (November 2018). Students Against Depression [22], and theDesk [23]. These systems mainly focus on supporting students that deal with depression and anxiety, but theDesk also offers some help with time management and study skills through videos and tips. The other systems were still in development or undergoing trials. According to the researchers neither of the systems that were online had been tested on effectiveness at that point in time [21]. Another project, Smart Reasoning Systems for Well-being at Work and at Home (SWELL), focused on the automated collection of data regarding work behaviour and stress levels using sensors and providing personalised feedback based on this information [24, 25]. A pilot study shows the potential of using sensors to collect data and to derive stress levels and working context of users, but that it is challenging to interpret this data, and that there are differences between the behaviour of different individuals [26]. Further research towards different models that can be used and the patterns in the behaviour of users is still required in order to take the next steps.

SMART SUPPORT & HUMAN VALUES

The projects and papers discussed above show that the research domain of smart support systems for students (or people in general) that experience stress, anxiety and/or have problems with time management is one that is actively being explored, but has no mature systems that provide help for both time management and stress, anxiety & depression in a smart manner. In order to create a system that can support students with these various and complex issues, we expect including the *human values* of students in both the design and functionality of the agent could be a successful approach. One of the most important researchers to address human values was Rokeach who created the Rokeach Value Survey (RVS) [27]. The RVS is a list of 18 instrumental values (that refer to preferable modes of behavior) and 18 terminal values (that refer to goals a person would want to achieve in their life). Since then values have also made their way into design for ICT projects; Batya Friedman was one of the first to introduce the notion of value sensitive design [28–30]. By introducing values in the design of the agent we can understand what motivates students to use certain applications. Since values are relatively stable for a human [31], but applications that a student uses can vary over time this is a good way

to group applications and show what values student promotes and demotes by using certain applications.

RQ 1 *What are existing applications & techniques that can provide insight and help with study behavior?*

There is an ample range of applications that track computer activity or provide (self-study) support available, thus only a few of these applications were analysed. All of the activity tracking tools that were studied are based on a combination of monitoring the applications that a user uses and time metrics. The support tools all feature short term feedback loops after study sessions or periodic reports.

3

Expert Interview Academic Counsellors

As part of the validation process of the initial design of the self-study support agent for students an expert interview was conducted. The goal of the interview was to gain a better understanding of the study problems that students encounter and what techniques could potentially be applied to help them effectively. The interview was conducted with three of the academic counsellors for the bachelors and masters of the Computer Science & Engineering education track.

Beforehand, we created a persona for a student and a counsellor based on the study of existing work, and with these personas we created a scenario in which an agent could support the student after consulting with the counsellor as a starting point for further research. Figure 3.1 shows an initial mock-up of the interactions between the agent and the student. The agent collects statistics about the applications the student uses, and provides two forms of feedback based on the collected information:

1. Immediate feedback in the form of pop-up messages or other notifications.
2. Longer term feedback in the form of reports and statistics on a dashboard or in e-mails.

The agent also has the ability to ask a student for clarification if it is unfamiliar with an application which the student is using. A more detailed explanation of this mock-up and the scenario surrounding it is included in Appendix A.

The expert interview consisted of an introduction to the topic of intelligent agents and the target group, followed by a questionnaire. Since the results from this questionnaire are not statistically significant because of the small group of experts, the questionnaire was intended to kick-start the discussion with the participants. After this initial discussion the participants were presented with three scenarios side by side in which the agent used different forms of providing (both direct and indirect) feedback, these scenarios were created as variations to the original mock-up discussed above. Several interactions were deliberately exaggerated in the scenarios to provoke a reaction from the counsellors. The counsellors were given the opportunity to indicate which aspects they did and did not like about the different scenarios after which a general discussion about the way the agent should work ensued. Both the questionnaire and the scenarios used in this expert interview are included in Appendix B.

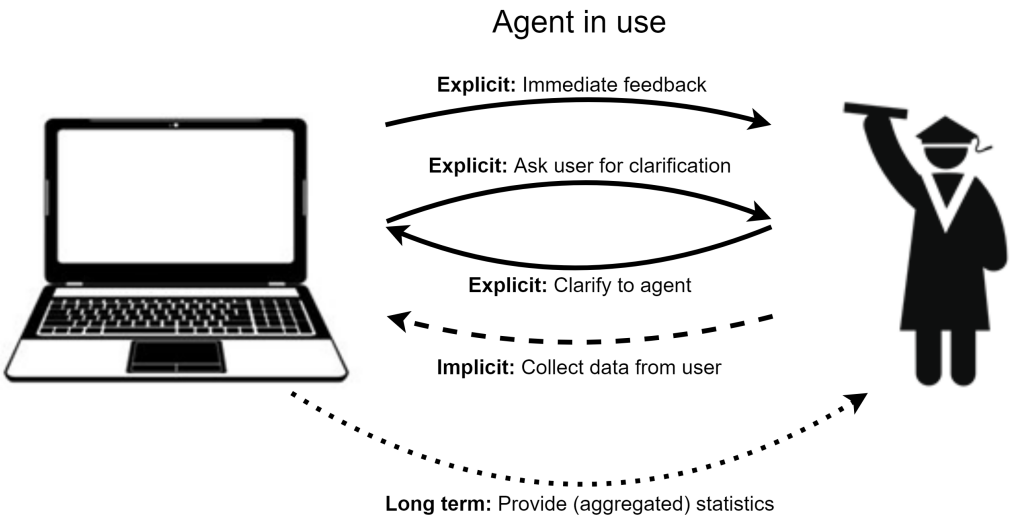

Figure 3.1: Initial mock-up of the interaction between the agent and a student.

In the following section the main points of feedback the counsellors provided on the different scenarios will be summarised. After that we present an adapted scenario of the interaction between student and agent which incorporates the suggestions provided by the academic counsellors during the interview.

3.1. RESEARCH SETUP

The research method of an *expert interview* was chosen because an expert interview is a good way to gain expert knowledge about a field of research, and to prepare the object that is under development for a test with actual users [32]. In our case the aim was to prepare a design of the agent for a prototype our Proof of Concept (PoC). According to Bogner and Menz there are different types of expert interview, with different purposes; our interview can be classified as an *exploratory expert interview* [33]. This means that the goal of the interview was to gain a better understanding of the study problems that students encounter and what techniques could potentially be applied to help them effectively. Next to that the interview was meant to generate hypotheses on which functionalities and interactions of the agent would be options for further research.

In order to structure the interview and to support generate an hypothesis for a potential design of the agent we prepared material to be discussed during the interview, this material is included in Appendix B. Because the questionnaire and scenarios used in the interview were prepared ahead of time, and are available as an appendix the interview is completely repeatable with the same structure. The interview started off with a questionnaire with statements that the counsellors could (dis)agree with on a Likert scale; the results were discussed afterwards. Subsequently the counsellors were presented with three different scenarios in which the interaction between the agent, student and academic counsellor were designed in different ways. These scenarios were discussed one by one and then compared to each other in order to create an hypothesis of what would be the preferred design of the interaction(s) according to the counsellors. These results were used to created an adapted design which is presented in the final section of this chapter.

The result of this interview is an audio recording which will be discussed in the next section. The counsellors were asked to provide their consent for the audio recording beforehand, and the interview was approved by the Human Research Ethics Committee (HREC) of the TU Delft. An explanation of the purpose of this interview, and the forms that were submitted to the HREC are included in Appendix D.

The summary that is presented in the next section was shared with the counsellors whom have participated in the interview for proofreading to confirm that it represents what they wanted to convey during the interview.

3.2. INTERVIEW RESULTS

In this section the results of the interview will be summarised. We will first discuss the feedback the counsellors provided per scenario and afterwards we will discuss general improvements and design changes that were proposed and incorporated as a result of this focus group.

3.2.1. AGENT COACHES STUDENT PASSIVELY

*In this scenario the agent fulfilled a passive role and only provided feedback in a **digest at the end of a (study) week**. The scenario furthermore mentioned that students can improve their own behaviour based on the feedback they receive, and that **students can share their digests** with the counsellor if they want to.*

The counsellors indicated that they liked the weekly digests, but thought at the same time that this feedback loop might be to slow, especially when a student starts working with the agent for the first time.

> *"A day, and then at the end of the week an overview as well. Especially at the beginning, because you're still learning to use it [the agent] it would be nice to get a daily digest."* - One of the counsellors, when asked what would be the shortest amount of time that should be covered in a feedback report. [1]

The counsellors suggested initially making use of daily digests, so students are able to rapidly respond to feedback the agent provides in the first period. They indicated that they liked the fact that the students have to take responsibility themselves, and have to adapt their goals themselves.

The counsellors also positively responded to the fact that students have the option of sharing their digests with the academic counsellors, this means that the students have to decide whether they are willing to share their data with the counsellor. But if they do, the counsellor can make use of the diagrams that are provided by the agent to assist the students.

3.2.2. AGENT COACHES STUDENT ACTIVELY

*In this scenario the agent fulfilled an active role and provided **immediate feedback** to the student once they became distracted. This did happen with the **importance of social interactions** for students in mind, meaning that the agent would allow usage for (social) apps such as Whats App rather than sending an immediate notification. The scenario furthermore mentioned that the student can **improve their own behaviour** based on the feedback they receive.*

The counsellors mentioned that the type of feedback this type of agent provides might be too intrusive for students. One of the counsellors used the analogy of "micro breaks" that were enforced by a tool on their computer. Since the tool popped up quite often and interrupted the workflow, it became a nuisance rather than a helpful tool which supports healthy workplace

[1] Translated; original: "... een dag, en dan aan het einde ook gewoon een week overzicht. Maar zeker omdat je er nog mee aan het trainen bent, is het juist wel handig om een dag overzicht te krijgen."

practices. If the tools' way of providing feedback would be too aggressive or if the alerts would be too frequent their concern was students might easily get fed up with the tool and no longer use it.

> *"It is annoying when you go to Facebook for a second, and that the tool would swiftly tell you 'you are slacking of, go do some work' ... it might be better if you can review and see: I have spent three hours on Facebook today, that is a lot, I want to lower that number."* - One of the counsellors [2]

As a second point the counsellors mentioned that they appreciate the idea of the tool allowing the use of social platforms since this is very natural for students to do, but at the same time they feared that students might have a hard time keeping track of how much they are using applications such as Whats App without any feedback. In the end they proposed a structure similar to the one described in the passive scenario where you can review your behaviour and set goals yourself when you receive a report after a predefined amount of time. Thirdly the counsellors noted they really liked the component where the student had the responsibility of improving their own behaviour (based on the feedback provided by the agent).

3.2.3. AGENT COACHES VIA THE ACADEMIC COUNSELLOR

*In this scenario the Agent didn't provide the students with any feedback on it's own but **shared the students' data with the academic counsellors**. The academic counsellors could then decide if or when they would contact a student.* This scenario was inspired by the method the NiceDay application uses to support people with psychological issues as discussed in section 2.3.

The counsellors had two main concerns regarding this scenario, in the first place they did not like the fact that the agent shared all information about students with them (since this is rather sensitive information and the student would have to consent to all of this information sharing beforehand), but more importantly because in this scenario the academic counsellor seems to be completely responsible for reaching out to the student.

> *"I got tilted by the third scenario [Agent Coaches via the Academic Counsellor] because the academic counsellor seems to be completely responsible ... we explicitly do not want that."* - One of the counsellors [3]

All three counsellors strongly agreed with this statement. The counsellors indicated that in an academic setting (as applies to TU students) students are expected to take responsibility and reach out to a counsellor in case they need help instead of the other way around. They mentioned that there are exceptions when it comes to students with issues regarding mental health and other severe problems, but that this is definitely not the default. An acceptable alternative to them would be that the tool indicates it might be a good idea for a student to contact the academic counsellors at a certain point. This would give them a nudge, but would ultimately mean that the student is still the one taking initiative.

3.2.4. COMPARISON & PROPOSED IMPROVEMENTS

Out of the three scenarios the counsellors indicated they liked the scenario in which the agent passively provided feedback the best, and the scenario in which the agent sends the student

[2] Translated; original: "Het is irritant dat als je op een gegeven moment naar Facebook switcht of zo, dat je dan heel snel zou krijgen van 'je bent niet goed bezig je moet wat doen' ... misschien zou je liever willen dat je kunt zien van: ik heb vandaag drie uur op Facebook gezeten, dat vind ik veel, ik wil dat getal naar beneden [brengen]."

[3] Translated; original: "Sowieso sloeg ik wel op tilt natuurlijk van scenario drie, omdat daar lijkt de hele verantwoordelijkheid bij de studie adviseur [te liggen] ... dat willen we expliciet niet."

data directly to the counsellors the least. They counsellors believed that it is the responsibility of students to contact a counsellor (and optionally share their data) at all times.

Between the scenarios in which the agent provides feedback to the student in an active or passive manner the counsellors indicated that providing feedback in a passive way would be more effective because it is less intrusive and more complete. However, they also suggested a method to improve the way the direct feedback works:
Initially the agent doesn't provide any immediate feedback and only generates daily (and weekly) digest reports. With these reports, that show the overall productivity of the student and what programs the student uses for how long, the student is offered the opportunity to set a limit on the amount of time a students spends on certain applications. When the student exceeds this limit they receive a notification stating this.
The counsellors expected students would appreciate the immediate feedback from the agent a more if they themselves had control over when and how the agent provides them with this feedback.

3.3. ADAPTED SCENARIO

In this section we introduce an adapted version of the interaction between agent, student and academic counsellor based on the points of attention that emerged from the expert interview described in the previous section.
Figure 3.2 shows an adapted version of the triangle of interactions between agent, student and academic counsellor. The core of the functionality where the agent monitors student behaviour and asks for clarification when necessary remains the same, these interactions are shown in the grey area in the figure. Apart from that the feedback the agent provides has changed in multiple ways:

- The proposed frequency of the digests has increased: students should receive daily digests in the beginning where they can review their productivity. This allows students to change their goals rapidly and find out what goals and restrictions work for them. A restriction could be setting a time limit for certain activities; these can be activities related to study subjects as well as social or relaxation. After a certain amount of time, when students have found a balance that works for them, the amount of digests can go down, for instance to one per week, to avoid annoying students with too much prompts and information. When exactly the amount of digests should be decreased and by how much may very well differ per student and is an option for future research.

- The student will initially receive no immediate feedback at all, to minimise potential annoyance for the student. The student will only start receiving notifications once they themselves have set a limit or *timeout* for the use of an application or a certain activity and they subsequently exceed that timeout. Students can adapt the timeouts they set over time to customise their experience.

- The agent will not have a direct channel of communication with the academic counsellor. Any data that is collected by the agent can be shared with the counsellor by students, if they are willing to do so.

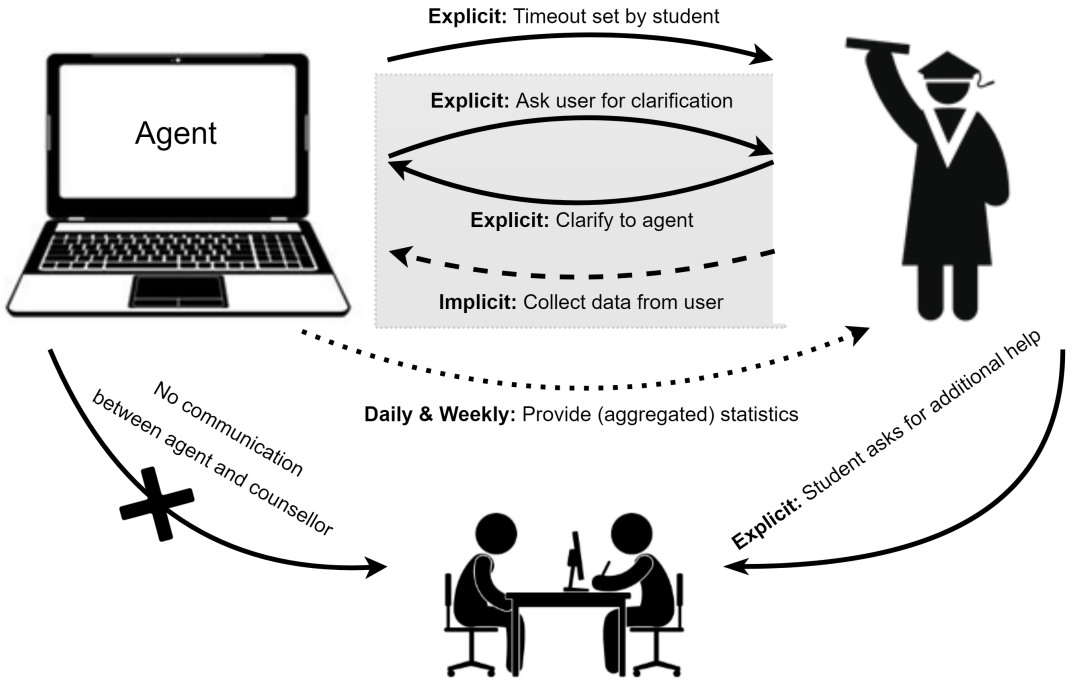

Figure 3.2: Redesign of the interaction between agent, student and counsellor.

Implementing the design changes mentioned above (according to the academic counsellors) has the benefit that students have more **independence** and **responsibility**, which are desirable traits in an academic setting. Furthermore if students themselves reach out when they need help, instead of the counsellors having to review the data of many students, simply saves the academic counsellors time and avoids privacy issues.

Next to feedback on the interactions between the agent, students and counsellors, that is incorporated in our design the counsellors also mentioned two research initiatives that focus on how students handle study tasks. The first initiative is the LASSI (Learning and Study Strategies Inventory) test, which is designed to gain insight in the learning and study practices of students [34, 35]. The second project is STELA[4] (Successful Transition in Education using Learning Analytics). STELA is a research initiative that focuses on the transition that students make from high school to university, and on how to make this transition easier for students. As part of the STELA project, a case study has completed which uses a LASSI test, and subsequently provides feedback to students about their learning skills & time management based on their answers on the LASSI test [36]. This is related to our research about self-study, but out of the scope of this thesis. Therefore we leave a potential connection of a self-study support agent to the STELA project as future work.

[4] https://stela-project.org/

4

Student Design Workshop

To verify the adapted scenario that was created after the expert interview with the academic counsellors (see chapter 3), and to gain more insight in what kind of tracking and feedback students value, a participatory design workshop was planned. The workshop was initially aimed at a group of approximately twelve first year Computer Science & Engineering students whom could be split into smaller teams. The setup was later changed to a one-on-one workshop due to a lack of applicants.

In the following section the methods used for this workshop and the setup will be discussed. Thereafter the results of the workshop will be summarised. Finally this chapter will conclude with an overview of the insights gained through the workshop.

4.1. Research Setup

This workshop was a combination of an interview and *participatory design*. Participatory design is a rather loosely defined research method that strives to enable end-users of a product to control what kind of product they receive in the end.

> *"...participatory design emphasises co-research and co-design: researcher-designers must come to conclusions in conjunction with users. So participatory design involves redesigning workplaces and work organisation as well as work tools. And it is iterative, allowing workers and researchers to critically examine the impacts of these incremental redesigns in progress."* [37]

The goal of this workshop was threefold:

1. Gain a better understanding of what kind of tracking students expect to be feasible (and acceptable in terms of privacy).
2. Co-designing the triangle of interactions between agent, counsellor and student.
3. Validate the design that was created as a result of the expert interview by cross examining it with the design created in the previous step of this workshop.

Due to the fact that the number of students that responded to the invitation for this workshop was too small for a proper group workshop, the setup was changed to a one-on-one format. A an introduction the workshop started with an explanation of contents to the participants. After which the participants were requested to sign an informed consent form because

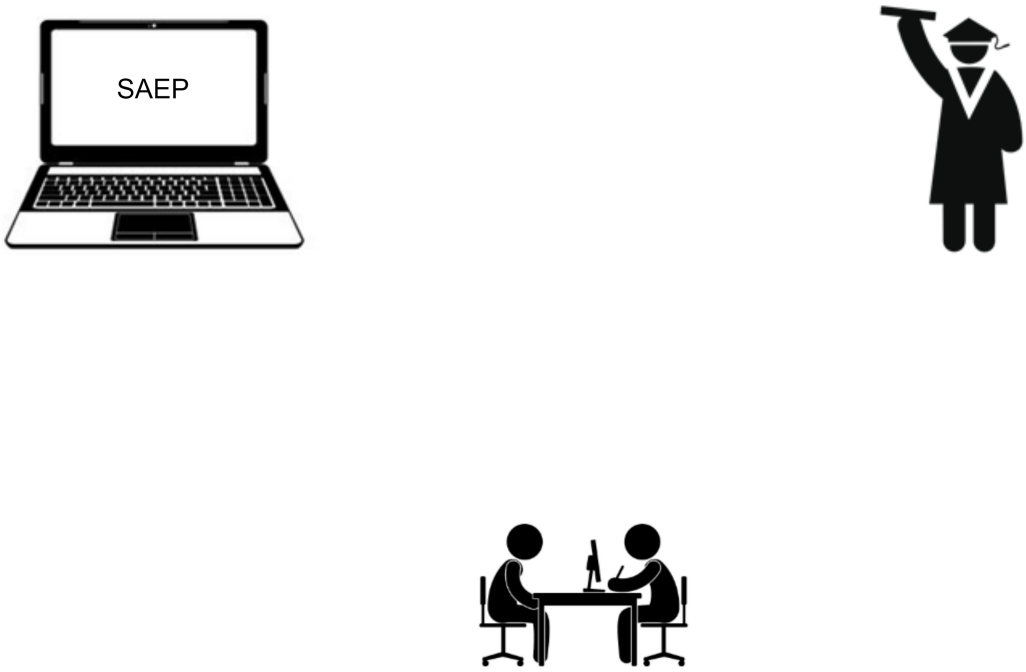

Figure 4.1: A clean sheet with just the agent, student and counsellor.

the remainder of the workshops was recorded. The remainder of the workshop was split into sections. First, the concept of the intelligent agent was explained to the participants. During the workshop the term *SAEP* (short for Socially Adaptive Electronic Partner) was used as a name for the agent. The students were then invited to discuss what activities they would track and why. After this discussion the students were provided with a near empty diagram including only agent, student, and academic counsellor. This was used as a starting point to co-design the triangle of interactions between agent, counsellor and student. The diagram is illustrated in Figure 4.1. The participants were tasked with thinking about interactions that could occur between these three components, and how these interactions would work. The resulting diagrams from this exercise were drawn on a whiteboard As a final step the students were shown the version of the diagram that was made after the interview with the academic counsellors to compare the two and discuss potential differences. This workshop is repeatable because all steps taken were recorded. However, it should be noted that because *participatory design* largely depends on input provided by the participants, the results may vary per participant. Since the number of participants in this experiment is very low the results of this workshop are not representative of the complete student body, but rather the ideas of two individual first year students.

The audio of both workshops was recorded to ensure no important information was lost. The participants were asked to provide their consent for the audio recording beforehand, and the interview was approved by the Human Research Ethics Committee (HREC) of the TU Delft. An explanation of the purpose of this interview, and the forms that were submitted to the HREC are in Appendix D

4.2. WORKSHOP RESULTS

Two one-on-one workshops were held. Both workshops lasted for about 75 minutes and resulted in a list of types of information that could be tracked, and a diagram that shows the interaction between agent, student and counsellor. In this section the outcome of these workshops will be summarised.

4.2.1. POTENTIAL TRACKING METHODS

During the workshop the participants were asked the following question: ***"Which student activities should be tracked and why?"***
The tracking of app names and times stamps were provided as a basis. Next to this both students mentioned window titles as an important source of information. They mentioned that this information could help the agent to understand whether an app was being used for studying or other activities, which is not always clear from just the name of an application. One of the students also mentioned (smart)phones as an important factor since it's easy for students to get distracted. Simply tracking whether the phone is in use could already provide an indication of whether a student is distracted or not.

> *"Ok, I'm thinking of the best thing that helps me avoid distractions, which is switching off my phone. [...] The phone is a major factor of distractions."* - A first year student.

Both of the participants realised that not every computer application is a clear indicator of whether a student is actually working on the study or not. An application such as IntelliJ[1] is a relatively safe indicator that a student is working on something study related but both students identified that especially the web browser as a rather large factor of uncertainty. The only way to reliably address this issue would be the introduction of additional (in browser) tracking. Since using the browser can either be good or bad for studying, based on the website or even web page that is being viewed, the web domains, pages and even page titles could be taken into account. The participants came up with several potential useful factors that could be related to the productivity of students. The trackable factors mentioned were: scrolling speed, amount of switching between programs and the number of open windows.

When asked which of the data collected using the methods mentioned above they would feel comfortable sharing both participants replied that app names and time stamps are acceptable, but window titles and especially any content are too personal to share.

> *"Me personally, yes, I would be ok sharing the name of the apps. I would not be comfortable sharing the titles; of course I'm not going to share the actual script on my screen."* - A first year student.

One of the participants was also fine with sharing information about top level domains visited in the browser (e.g. youtube.com), but the other student thought this was already too personal. The suggestions regarding data tracking and privacy that both participating students provided during the workshop were written down on a whiteboard, and are included as a reference in Appendix C.

4.2.2. INTERACTION WITH THE AGENT

The second part of the workshop was used to create a diagram based on the input of the students starting from just agent, student and academic counsellor. The results of this exercise are presented in Figure 4.2 & Figure 4.3. Both participants indicated that they would like to

[1] https://www.jetbrains.com/idea/

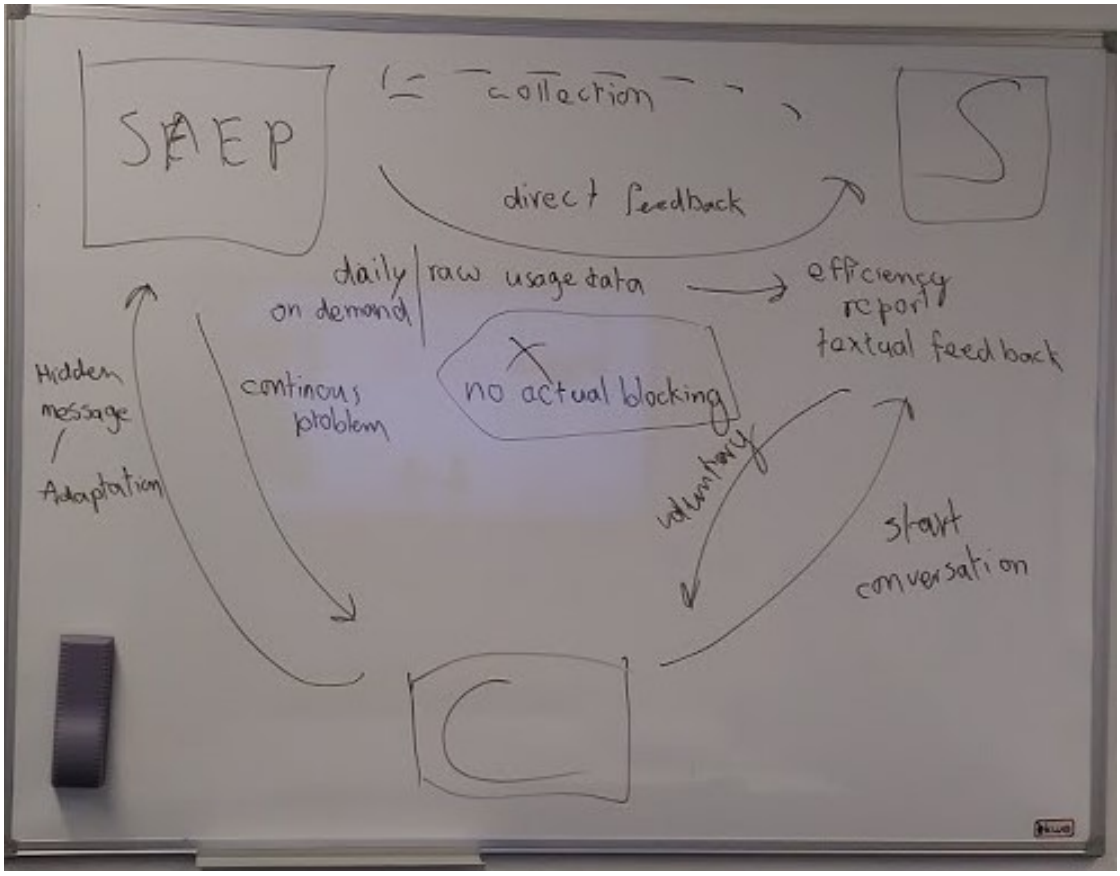

Figure 4.2: A diagram of the interactions between agent, student and counsellor created with one of the students.

receive periodic feedback from the agent about their behavior. This should be in the form of daily and weekly digests, which can be accessed on a dashboard. One of the students mentioned that the agent could also notify the student of study progress using pop-ups, but that those should never be sent while the student was working properly, since this could disrupt the workflow. The pop-ups could work to reinforce positive behavior. The other student was even more conservative when it came to pop-ups or other *aggressive* messages.

> *"Let the user to whatever he wants, but at the end of the day tell him, you've been doing that wrong [...], if you are too aggressive to the user, he might think I don't want this app"* - A first year student.

The notion of giving students periodic feedback on a dashboard and conservative use of more intrusive feedback methods such as pop-up messages which the participants had are very similar to the ideas the counsellors had on this topic.

The participants had different ideas about the sharing behavior of the agent towards the academic counsellor. One of the participants proposed that the agent would continuously share information with the counsellors and that the counsellors could in turn review this information when desired. The counsellors could then change the settings of the agent remotely to better suit the needs of the student or take direct action. The other participant was more reserved regarding the agent sharing data of it's own volition and proposed that the student could choose

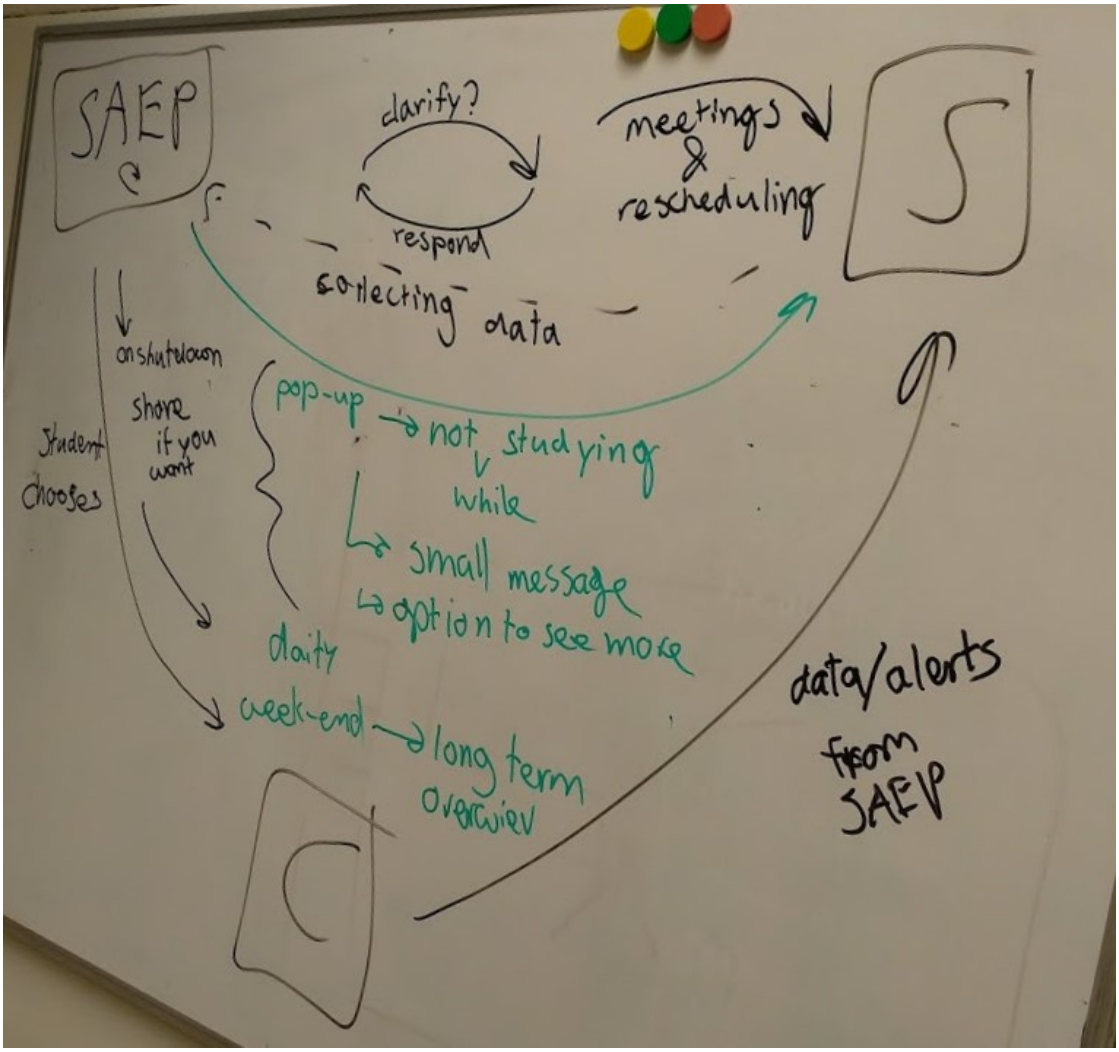

Figure 4.3: A diagram of the interactions between agent, student and counsellor created with one of the students.

what information they wanted to share, and had to consent every time information was shared. Alternatively the student could check a box to explicitly consent to automated sharing of data in the future. Both students were in agreement on the fact that the counsellors could reach out to a student if they thought they could help a student in some way. The student could then decide to accept or decline this invitation.

After the diagrams were completed, the participants were shown the diagram that was created after the expert interview with the academic counsellors (as shown in Figure 3.2). All of the diagrams were very similar with respect to the interaction between agent and student. The agent collects data, requests clarification when needed, and subsequently provides feedback on a dashboard and via a limited amount of pop-up messages.
There were larger differences in the interactions between counsellor and agent, and counsellor and student. Both participants in the workshop proposed that the agent would share some data with the counsellor with varying degrees of automation, but the counsellors indicated that

they were against any automated sharing of data. Their reason for this was twofold: it would be rather invasive for the privacy of the student if the agent were to share data in an automated fashion, but more importantly, the counsellors would become (partially) responsible for arranging help for students. After explaining the view of the counsellors to the participants of the workshop, both appreciated the importance of having the students take initiative on their own. One of the participants did propose the agent could encourage students to reach out to the counsellors when required, for instance by proposing to plan a meeting with a counsellor.

> *"What I would like for the SAEP to suggest, in one of the scenarios where I should contact the counsellor, make it easy for me to a point where it's a click of a button"* - A first year student.

By using the agent to invite the student to a meeting with the counsellor, the bar is lowered. It becomes easier for the student to make an appointment with the counsellor if the agent suggests this might be a good idea, and facilitates this process as much as possible. Rather than requiring the student to do this all on their own.

4.3. INSIGHTS GAINED

Both of the students who participated in the workshop were enthusiastic and saw merit in the tool to assist students. One of the participants even explicitly mentioned that he had some friends that could use a tool like this. This shows that there is demand for the agent from the perspectives of both academic counsellors and students.
In respect to data collection it has become clear that there needs to be a division in data that can (anonymously) be shared with the developer and academic counsellors for data mining purposes, and data that will remain only on the device of the student. The agent can for instance use the titles of windows to improve the classification of certain activities as studying or social, but this information has to be deleted afterwards.
When it comes to the counsellor reaching out to the student or vice versa, it is interesting to note that both of the students initially thought it would be a good idea for the academic counsellor to reach out to the student, but that the counsellors had a different opinion. Even though the students appreciated the counsellor's point of view, this subject could be explored further to find a compromise that is acceptable for both students and counsellors.

RQ 2.1 *What should the triangle of interactions between student, agent and counsellor look like?*

Based on a focus group with domain experts and subsequent validation with two potential end-users, we can conclude that the triangle depicted in Figure 3.2 is a suitable design. There should be interactions between agent and student on several levels: data collection by the agent, clarification from student to agent, and notifications from agent to student. The student is responsible for contacting the counsellor, and finally there should be *no* direct interaction between agent and counsellor.

RQ 2.2 *What functionalities does the agent need to fulfil its role in the triangle?*

To be of added value to the student the agent needs to do three things:

1. To establish what activity the student is conducting.
2. To assess whether this activity is in line with the goals of the student.
3. To provide appropriate feedback to the student based on its assessment.

5

Proof of Concept

To provide a Proof of Concept (PoC) for an intelligent agent that reasons about the activities of students, a prototype was constructed. The prototype consists of a separate activity tracker which collects activity data, an environment connector that parses the data and a GOAL agent which reasons about the activities of the student. In this chapter we explain how these components interact together and how the agent reasons about the activities.

5.1. Prototype structure

The prototype for the agent consists of three different components. An illustration of the flow and structure of the prototype is presented in Figure 5.1.
The first component in the flow is the **activity tracker**. The activity tracker is completely separated from the other two components and is used to track the applications which are used on a computer in combination with time stamps. The disconnect between the activity tracker and the other components of the prototype was introduced for practical reasons, and is by no means a fundamental requirement. In fact, it would be desirable to integrate the activity tracker with the other components if the agent is developed further. This way students could use an agent that provides real-time feedback based on current activities. The information that is collected with the activity tracker is subsequently exported to a JSON[1] file.
The second component of the prototype is the **environment connector**. This component parses data that was exported by the activity tracker and processes it into a format usable for the third component, the **agent**. The agent receives information from the environment connector (in the form of *percepts*), combines this with information that is already available (its *knowledge* and *beliefs*) and decides on what *action* should be taken. The determined action is then communicated back to the environment connector which in turn executes it. The concepts of *percepts*, *knowledge*, *beliefs* and *actions* will be explained in subsection 5.1.3.
In the following three subsections each of the three components that together form the prototype will be explained in more detail.

5.1.1. The Activity Tracker

The activity tracker is a slightly adapted fork of the open source project ActivityWatch[11]. This project was used as a starting point because it offers the functionality required for our Proof of

[1] http://www.json.org/

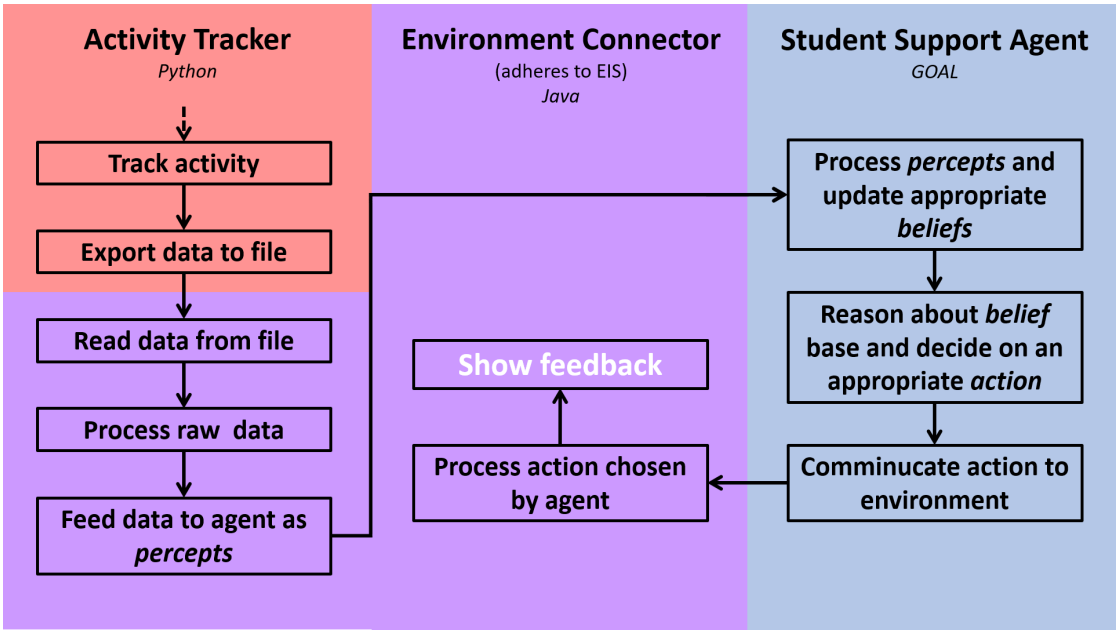

Figure 5.1: An overview of the interaction between components.

Concept agent and creating a custom activity tracker is outside the scope of this thesis project. The selection of specifically ActivityWatch and not another tool was motivated in section 2.2.

ActivityWatch offers various tracking options, such as a computer app, a browser extension and an Android application. For this study only a small selection of these options was used. Only the stand alone desktop application was used to collect data for our PoC. While using more sources of data could improve the ability of the agent to assess student behavior there are two main reasons the prototype is limited to usage of the desktop application. First, the scope of this PoC is small. The goal is to prove that an agent can logically reason about student activity, and the activity data collected by the desktop application is sufficient to achieve this. Second, collecting a lot of data about students is very privacy sensitive. The desktop application already collects information about applications that are being used, and the titles of windows. However, the browser extensions can track exactly which web pages were visited, and the mobile app can track the use of mobile apps as well. This raises many concerns, which were voiced by both academic counsellors and students whom were interviewed, as discussed in previous chapters. The measures that were taken to perform this PoC within ethical guidelines will be described in chapter 6.

5.1.2. THE ENVIRONMENT CONNECTOR

The environment connector acts as a conductor between the outside world and the agent. It parses the activities a student conducts and feeds them to the agent in usable chunks. After the agent has processed the activities and decided which action should be taken, the environment connector receives these instructions, and subsequently executes them. In the prototype, the only possible action the agent can take is sending a message. This message is shown in a GUI overview by the environment connector and is an abstract representation of the agent advising the student.

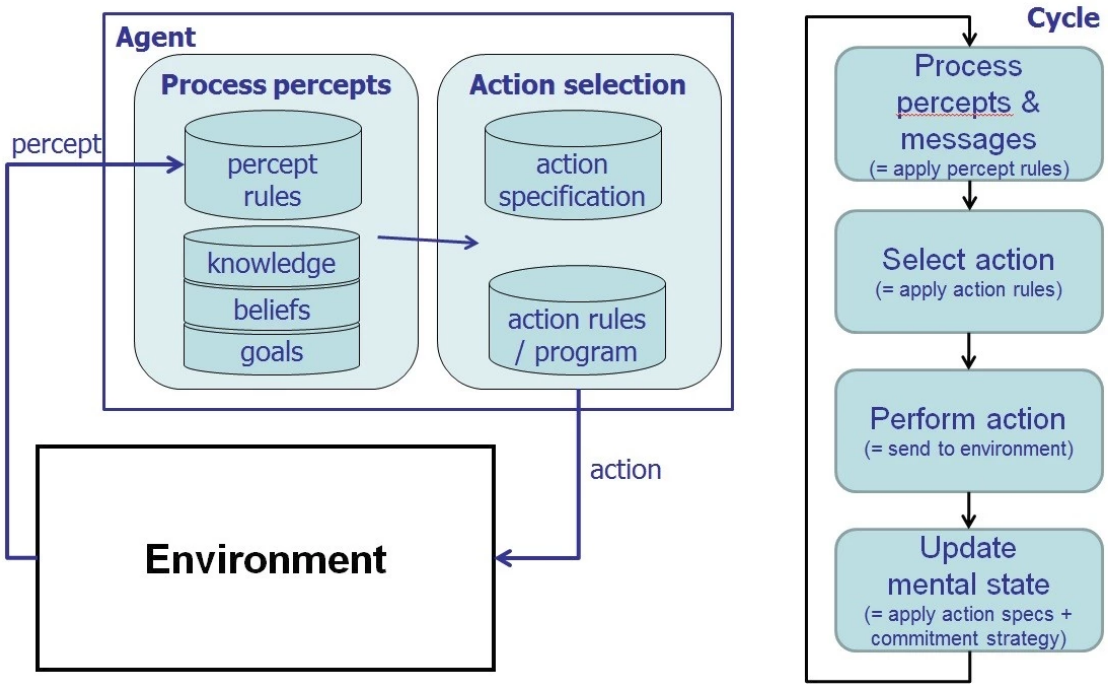

Figure 5.2: An visualisation of the inner workings of GOAL. Image taken from https://goalapl.atlassian.net/wiki/spaces/GOAL/overview, March 2019

```
activity("eclipse.exe", "14-01-2019", 600). %Percept

appUsage("eclipse.exe", "14-01-2019", 7200). %Belief

```

Figure 5.3: Activity percepts getting processed into usage beliefs.

SIMULATION OF REAL ACTIVITY

Since there is a disconnect between the activity tracker and the other components of the prototype for practical reasons, the analysis of the tracked data does not happen in real time. In order to simulate a scenario where the agent provides periodic feedback on student behavior the environment connector has a way of feeding data to the agent in a periodic fashion. The connector can be configured to feed all activity that occurred in a time window with duration X to the agent every Y milliseconds. This allows the agent to reason about the activity of a student as if it happened in real time.

5.1.3. THE STUDENT SUPPORT AGENT

The PoC agent was created using the GOAL[2] programming language [38]. GOAL was selected instead of another programming language because this project is related to other projects that research the applicability of agents in different domains. Several of these projects use GOAL for their prototypes as well [39]; thus using GOAL for this project is a logical choice since this

[2] https://goalapl.atlassian.net/wiki/spaces/GOAL/overview

allows for an easier exchange of knowledge, and makes the project more accessible to other researchers working on similar subjects.

THE INNER WORKINGS OF GOAL

Figure 5.2 shows a more detailed overview of the inner workings of GOAL. Starting from the bottom left; the environment is simulated by the **environment connector** which provides the agent with percepts. *Percepts* represent events that happen in the outside world that can be observed by the agent. The agent processes these percepts and adjusts its beliefs accordingly. *Beliefs* represent information the agent has that can be updated over time. Next to beliefs the agent has knowledge. *Knowledge* is information that is related to concepts or definitions and does not change. Finally the agent may adopt *goals*. Goals represent states the agents wants to realise.
Based on its beliefs, combined with the knowledge and goals which are present, the agent selects an appropriate *action* which is subsequently executed.

Figure 5.3 shows an example of an percept and a belief an agent may have. The percept `activity(Appname, Date, Duration)` is processed by the agent and leads to a belief `appUsage(Appname, Date, DurationTotal)`. The usage of applications is aggregated by the agent over the course of the day.

THE GOOD, THE BAD, AND VALUES

As explained in the previous sections, the agent reasons about the activity of the student and provides them with feedback. However, not all activities can unambiguously be defined as *good* or *bad* for a student. The effect of any activity depends on multiple factors, for instance, using an application that is generally associated with studying such as an IDE like Eclipse[3] is usually positive for study progress, but this can be influenced by other factors such as the amount of time a student spends on studying consecutively or other goals a student has.

To deal with this uncertainty and risk of ambiguous classification, the notion of *values* was introduced. The agent does not simply attribute a binary value of *good* or *bad* to an application, but has a list of values associated with an application. Values can show what drives a student to use a certain application as *academic success* is not the only thing they deem important. The concept of values was introduced in section 2.4.

Figure 5.4 shows a tuple of an application and a list of affected values. An application can *promote* various values at the same time, while other values remain unaffected. The introduction of multiple values which are affected in different ways by the use of one application enables the agent to view applications in a more refined way.

```
("chrome.exe", [
    ("social", 0.2),
    ("physical", 0),
    ("study", 0.8)
]).

```

Figure 5.4: Mapping between an application and tuples of associated values.

SETTING UP NORMS

Because every student has their own needs, it does not make sense for the agent to enforce arbitrary targets by default. In principle the agent just processes the events it observes and can

[3] https://www.eclipse.org/ide/

provide insight by sharing statistics. When the student actively wants to change their behavior they can set *norms* for themselves. In literature norms were used as a construct to regulate the behavior of an agent, making sure it does not do anything undesirable [40, 41]. In this prototype norms are used to regulate the behavior of agent and student to an extent. By default, the agent has a relatively passive role but this changes when the student sets norms. A norm can for instance be related to the usage of an application, or the promotion / demotion of a specific value that is important to the student. The agent will now, encourage the student to comply with the norm. The agent will take action when it observes certain behavior related to a norm that is in place. This means that norms set by the student regulate the behavior of the agent which, in turn, supports the student to help them comply with the norm they set.

Figure 5.5 shows several different examples of norms a student can set. A student can set an *appMinNorm(X, Y)* or *appMaxNorm(X, Y)* which is simply a minimum or maximum amount of time a student wants to use an application during a day. Alternatively a student can set norms related to the promotion or demotion of values. This allows students to set goals that are not related to a single application, but larger goals such as working on their study or social wellbeing.

The agent matches all activities that occur and values that are affected by these activities with norms set by the student. The agent then sends notification to the student once the target for a norm was reached, or when the student has passed the half way point towards a target.

```
1 appMaxNorm("telegram.exe", 3600).
2
3 valueMinNorm("study", 7200).
4
5 valueMaxNorm("social", 1800).
6
```

Figure 5.5: Several norms related to app usage and values.

5.2. PROTOTYPE VERIFICATION

In chapter 6 we present an analysis of sample data gathered from several students. In this section we show that these are reliable by verifying the correctness of the prototype described above. According to the International Software Testing Qualifications Board (ISTQB) the act of software verification is:

> *"Confirmation by examination and through provision of objective evidence that specified requirements have been fulfilled."* - ISTQB [42]

In other words, we mean to verify whether the prototype was built functions correctly without faults, or loss of important information. The next subsections will discuss the methods of verification used for each of the components that are part of the prototype.

5.2.1. ACTIVITY TRACKER VERIFICATION

The activity tracker is a fork of the ActivityWatch project [11], as was explained at the beginning of this chapter. The project has continuous integration (CI) and is well tested with a branch coverage of more than 90% for the core components as well as a substantial amount of integration tests [4]. The project is open source and has an active community of developers and users, which

[4]The latest CI builds can be viewed here: https://travis-ci.org/ActivityWatch/activitywatch

improves the rate at which faults are discovered and fixed. Therefore, no further verification of the activity tracker was conducted.

5.2.2. ENVIRONMENT CONNECTOR VERIFICATION

The Environment Connector was built as a part of this PoC and tests were written and executed to ensure it functions as expected. Especially regarding parsing of activity data and processing the times that a student is away from keyboard (AFK) various tests were written. This was done to build confidence in the correctness of the activity information the agent receives from the connector. The GUI of the connector was not tested automatically as this is not a priority for this PoC.

5.2.3. GOAL AGENT VERIFICATION

To verify the prototype agent has a correct way of reasoning about student data the flow of data needed to be analysed. The agent implemented in GOAL can be viewed as an abstract entity with states. Each percept which is *observed* by the agent leads to a series of state changes, and leads to a new stable state after a finite amount of cycles. This state remains the same until a new observation causes another series of state changes in turn. This behavior relies on the fact that the percept which is observed by the agent is correct and there are no faults encountered when the agent processes the observation and the consequences thereof.

SAFETY AND LIVENESS PROPERTIES

Because there are many different observations which can lead to many different states, unexpected results could occur. To systematically determine the agent shows desirable behavior the *liveness* and *safety* properties of the GOAL agent we proved [43, 44]. *Safety* is a property that ensures something bad, such as the agent crashing when given a correct input, does not happen, whereas *liveness* is a property that ensures something good will eventually happen, such as a correct input leading to the insertion of a belief or an action [45]. Together these two properties ensure that a valid input always leads to a result.

Safety and liveness properties of a program can be shown using different proofing methods. Several alternatives were considered for the verification of the GOAL agent program. Linear Temporal Logic (LTL) was considered as a logical toolbox [46, 47]. However LTL has insufficient tools to deal with quantitative reasoning which is part of the GOAL agent (e.g. comparing values to see whether a norm was exceeded). Additional explanation regarding the use of LTL was included in Appendix E.
The Temporal Trace Language (TTL) is another alternative which was considered [48]. TTL does include tools that can be used to represent quantitative relations. However, the problem of systematically formalising the sequence of possible states that form the desired behavior of the GOAL agent remains:

> *The problem of checking relationships between dynamic properties of a system, identified above as one of the desiderata for analysis techniques, is essentially the problem of justifying entailment relations between sets of properties defined at different aggregation levels of a system's representation.* [48]

There is a gap between formally defined behavior and the concrete implementation of rational agents which is difficult to bridge [49–52]. Providing (1) an actual formalisation of the state changes the agent may go through, and (2) proving this formalisation corresponds with the concrete implementation of the PoC, is outside the scope of this thesis. We have opted to verify

the behavior of the GOAL agent in a concrete way by using the automated testing framework that GOAL offers [53].

AUTOMATED TESTING IN GOAL

We have used the the automated testing framework introduced in the work of Koeman et al. autmated failure detection in GOAL agents [53] to test the behavior of the GOAL agent. The grammar of the test language of the framework introduces two important operators, `never` Φ and Φ `leadsto` Φ', and is powerful enough to detect all types of failures that were identified in GOAL, because they can be used to verify the safety and liveness properties of an agent [54]. Thus the safety and liveness properties of the GOAL agent can be tested by using test cases that were designed with the automated test framework.

SAFETY

GOAL tests support the possibility to test that *bad* things never happen (given "bad thing" b we can define: $\Box\neg b$ [46]). This can be achieved by using the `never` Φ construct [55]. Figure 5.6 shows an instance of a test case which tests a message will never be sent about an application if there is no norm in place regarding that application.

```
1 % Never send a message related to an application if there is no norm about it.
2 never done(sendUsage(App,"appMaxNorm",_)), not( bel(appMaxNorm(App,_)) ).
3
```

Figure 5.6: Example of verifying a safety propery.

LIVENESS

GOAL tests support the possibility to test that something *good* will eventually happen given a certain correct input (given correct input a and "good thing" b we can define: $a \rightarrow \Diamond b$ [46]). This can be achieved by using the Φ `leadsto` Φ' construct [55]. Figure 5.7 shows two instances of test cases that test the liveness property. The first test verifies that perceiving a certain activity will eventually lead to the insertion of a belief regarding that activity. The second test verifies that if the usage of an application exceeds the norm for this application a message will be sent regarding this occurrence.

```
1 % Perceiving an activity leadsto statistics being tracked about this activity
2 percept(activity(App, _, _))
3     leadsto bel(appUsage(App, _, _)).
4
5 % If an app is used more than the maximum on a day a message is sent.
6 bel(appUsage(App, _, Amount), appMaxNorm(App, Limit), Amount >= Limit)
7     leadsto done(sendUsage(App, _, _)).
8
```

Figure 5.7: Example of veryfiying the liveness property.

5.2.4. CONCLUSION

In this chapter we showed that our prototype consists of an activity tracker, an agent and a connector between the two. Together they can be used as a PoC *self-study support agent*. We also discussed our efforts to verify whether the prototype functions correctly, thus we are confident that this is the case. In the next chapter we will present the results of an experiment where our PoC was used to track several students and subsequently analyse their activities.

6

EXPERIMENTAL STUDENT TRACKING

To explore the potential of the Proof of Concept (PoC) prototype we collected real activity data from several first year Computer Science and Engineering students. Subsequently we performed an analysis on this data. The goal of this experiment was to show that it is feasible to collect data from students as they work, and analyse this data with an agent and provide feedback. In the remainder of this chapter the experiment setup and the results will be discussed.

6.1. EXPERIMENT SETUP

For this experiment the participants were requested to install the data tracking application discussed in subsection 5.1.1 on their computer, and run the tracker for a period of two weeks. The purpose of this experiment was to show that the prototype agent is capable of providing some minimal form of feedback on the behavior of sample students based on their normal activity.

The participating students were requested to export and share the data after the finalisation of the data collection, so they had full control of what data they shared themselves. Three students started the experiment out of which two shared their data at the end of the tracking period. The participants were requested to provide their consent for data collection beforehand, and this experiment was approved by the Human Research Ethics Committee (HREC) of the TU Delft ahead of time. An explanation of the purpose of this experiment, and the forms that were submitted to the HREC are included in Appendix D.

6.2. DATA ANALYSIS

For this study, the data of two students was collected over a period of approximately two weeks. Due to technical issues, the collection windows of the students start one week apart. On average we would expect a student to spend approximately 18-26 hours on study related activities on their laptop during the tracking period. This estimate is based on adding the expected hours of self-study defined for the Computer Science and Engineering curriculum [1], and a total of

[1] https://www.tudelft.nl/en/education/programmes/bachelors/cse/bachelor-of-computer-science-and-engineering/degree-programme/

8 hours scheduled labs related to programming and data basing courses [2]. Since the students also had a math related course during the experiment period, their time spent on the computer might be somewhat lower, as calculations are often done on paper, which was not tracked for this experiment. The expected amount of hours spent by a student studying may vary per day, because students do not always study during weekends, or could have other activities on a certain day. For this experiment we tracked students for the entire week, including the weekend.
Each of the applications used by the students received an arbitrary mapping to the values *study* & *social* to facilitate analysis of the raw data by the agent. For most applications a mapping of either `{study: 0, social: 1}` or `{study: 1, social: 0}` was used, because one of the values is way more likely to be promoted by the use of a certain application than the other. The web-browser is an exception in this mapping, and treated differently per test student.

6.2.1. STUDENT #1

The activities for student #1 were recorded from *25-03-2019* starting from 12:30, until *07-04-2019*. This time window was used because during these weeks, the student had a normal schedule with a division between lectures, lab sessions and self study. Student #1 used a laptop with Windows as operating system during the experiment. Table 6.1 shows the applications used most by student #1 during the tracking period. One of the values *study* & *social* was assigned to each application. Student #1 has indicated that he/she used the web-browser Edge for study related browsing, and the web-browser Chrome for relaxing and social browsing. Because of this we were able to assign a single value to both browsers with confidence. Together, both web-browsers account for *72%* of the time student #1 spends on his/her laptop.

Activity	Assigned Value	Percentage of Time
ApplicationFrameHost.exe (Web-browser) [3]	Study	64%
idea64.exe (IntelliJ) [4]	Study	9%
chrome.exe (Web-browser) [5]	Social	8%
WINWORD.EXE [6]	Study	8%
explorer.exe (System Explorer)	Study	4%
EXCEL.EXE [7]	Study	2%
iTunes.exe [8]	Social	2%
java.exe [9]	Study	2%
sourcetree.exe [10]	Study	1%
others	-	1%

Table 6.1: An overview of the applications used most frequently by student #1 and his/her mapped values.

Figure 6.1 & Figure 6.2 show the activity of student #1 on his/her laptop in hours per day divided over study and social related applications during each of the tracked weeks. When we

[2] https://www.tudelft.nl/en/education/programmes/bachelors/cse/bachelor-of-computer-science-and-engineering/curriculum/
[3] https://www.microsoft.com/en-us/windows/microsoft-edge
[4] https://www.jetbrains.com/idea/
[5] https://www.google.com/chrome/
[6] https://products.office.com/en-gb/word
[7] https://products.office.com/en-gb/excel
[8] https://www.apple.com/uk/itunes/
[9] https://www.oracle.com/technetwork/java/javase/overview/index.html
[10] https://www.sourcetreeapp.com/

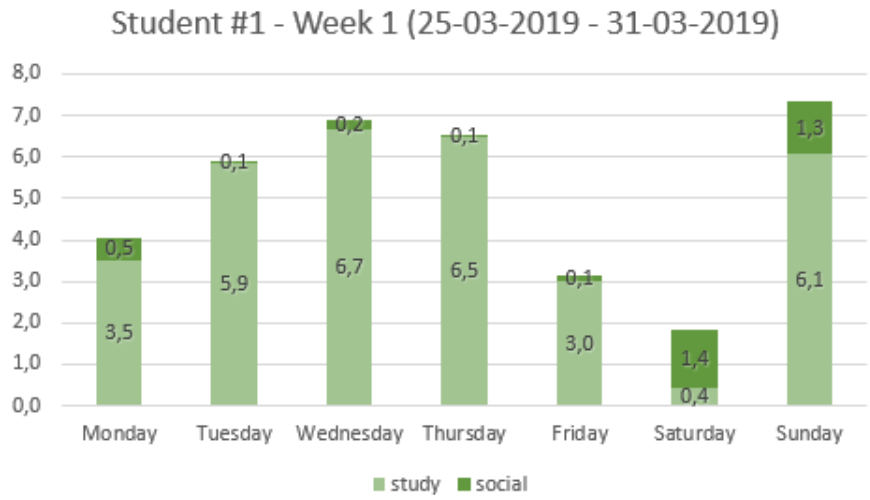

Figure 6.1: The activity of student #1 on his/her computer during week 1, with weekdays on the x-axis and hours of usage on the y-axis.

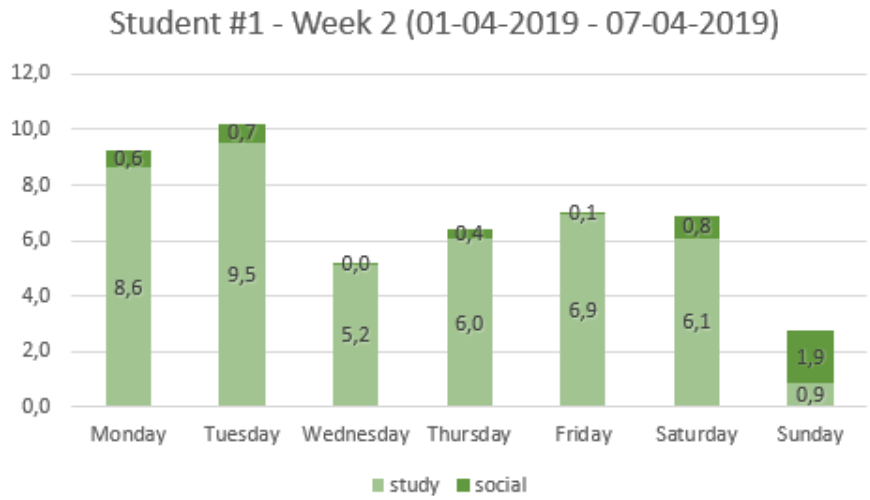

Figure 6.2: The activity of student #1 on his/her computer during week 2, with weekdays on the x-axis and hours of usage on the y-axis.

add this data, which is shown in Table 6.2 we can conclude that student #1 spent respectively *32,0* hours and *43,2* hours studying during the two weeks of the experiment, this is somewhat higher than the expected 18-26 hours.

Week #	Time on laptop	Time promoting study	Time promoting social
Week 1	35,7 hours	32,0 hours	3,7 hours
Week 2	47,8 hours	43,2 hours	4,6 hours

Table 6.2: An overview of the time student #1 spent on his/her laptop per week, and the amount of time he/she spent promoting the study and social values.

6.2.2. STUDENT #2

The activities for student #2 were recorded from *01-04-2019* until *14-04-2019*. This student started the experiment later than student #1 due to the fact that he/she used MacOS as operating system which required some additional time to set up. Table 6.3 shows the applications used most by student #2 during the tracking period. Student #2 did not use different web-browsers for activities associated with studying or socialising respectively. Since there is no clear way to distinguish time spent on studying versus time spent on social websites using the data gathered for this experiment, we have created two different mappings for the time spent in the web-browser. In *mapping A* the student is assumed to be studying the whole time he/she used the web-browser, this is shown in Figure 6.3 & Figure 6.4. In *mapping B* half of the time spent in the browser is mapped to studying, and the other half to socialising. This is shown in Figure 6.5 & Figure 6.6.

It can be noticed there is quite a large difference between the time spent studying and the time spent socialising in mappings A & B as the student spent a significant amount of his/her time (63%) using the web-browser. Table 6.4 shows the total amount of hours student #2 spent on his/her laptop during the two weeks of the experiment. The table also shows the amount of time student #2 spent promoting the study and social values using mappings A & B.

Activity	Assigned Value	Percentage of Time
Google Chrome (Web-browser) [11]	Study / Social	63%
webstorm [12]	Study	8%
idea (IntelliJ) [13]	Study	7%
Preview [14]	Social	5%
Terminal [15]	Study	4%
java [16]	Study	2%
Keynote [17]	Study	2%
WhatsApp [18]	Social	2%
Finder (System Explorer) [19]	Study	1%
Messages [20]	Social	1%
Pages [21]	Study	1%
others	-	4%

Table 6.3: An overview of the applications used most frequently by student #2 and his/her mapped values.

[11] https://www.google.com/chrome/
[12] https://www.jetbrains.com/webstorm/
[13] https://www.jetbrains.com/idea/
[14] https://support.apple.com/guide/preview/welcome/mac
[15] https://support.apple.com/guide/terminal/welcome/mac
[16] https://www.oracle.com/technetwork/java/javase/overview/index.html
[17] https://www.apple.com/keynote/
[18] https://www.whatsapp.com/?lang=en
[19] https://support.apple.com/en-us/HT201732
[20] https://support.apple.com/explore/messages
[21] https://support.apple.com/pages

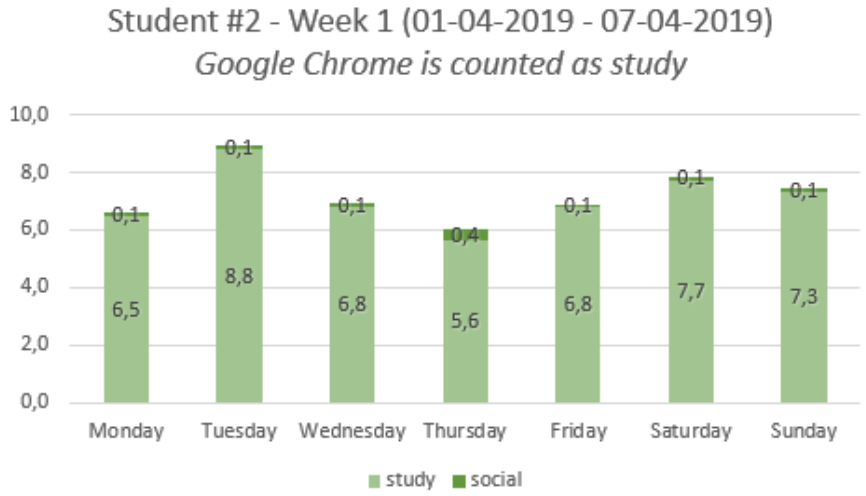

Figure 6.3: The activity of student #2 on his/her computer during week 1, with weekdays on the x-axis and hours of usage on the y-axis. Chrome is completely mapped to the study value in this graph.

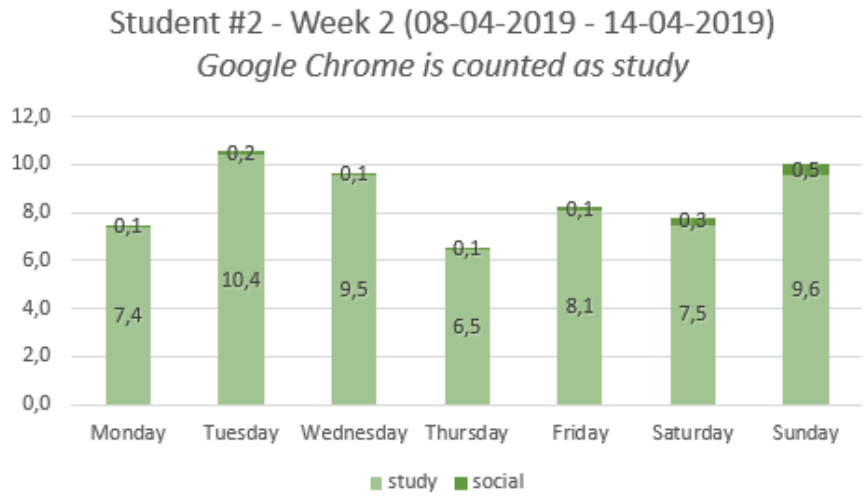

Figure 6.4: The activity of student #2 on his/her computer during week 2, with weekdays on the x-axis and hours of usage on the y-axis. Chrome is completely mapped to the study value in this graph.

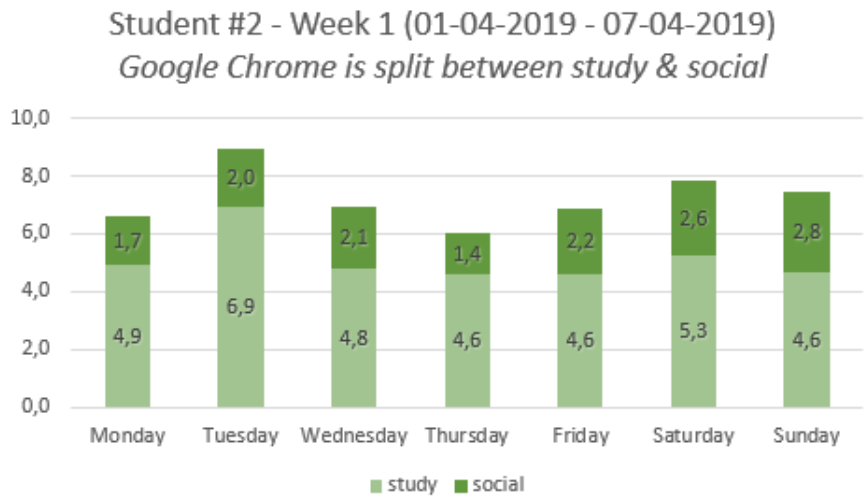

Figure 6.5: The activity of student #2 on his/her computer during week 1, with weekdays on the x-axis and hours of usage on the y-axis. Chrome is partially mapped to the study value (0.5), and partially mapped to the social value (0.5 in this graph).

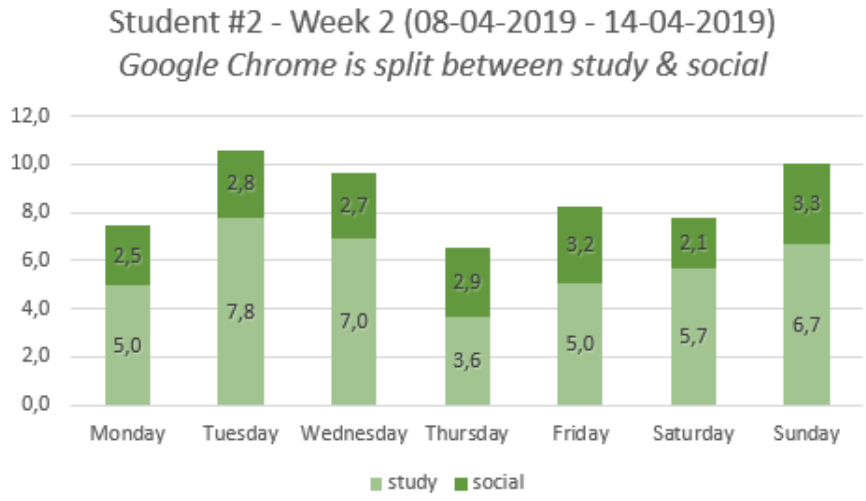

Figure 6.6: The activity of student #2 on his/her computer during week 2, with weekdays on the x-axis and hours of usage on the y-axis. Chrome is partially mapped to the study value (0.5), and partially mapped to the social value (0.5 in this graph).

Week #	Mapping	Time on laptop	Time promoting study	Time promoting social
Week 1	A	50,7 hours	49,7 hours	1,0 hours
Week 2	A	60,4 hours	59,0 hours	1,4 hours
Week 1	B	50,7 hours	35,8 hours	14,9 hours
Week 2	B	60,4 hours	40,8 hours	19,6 hours

Table 6.4: An overview of the time student #2 spent on his/her laptop per week, and the amount of time he/she spent promoting the study and social values. Mapping A classifies the web-browser as completely study related, mapping B maps the web-browser as half study related and half social.

WEB-BROWSER IMPACT

We can can conclude there is indeed a **rather large difference** of *13,9 hours* (27% of the total amount of hours spent on the laptop) in week 1 and *18,2 hours* (30% of the total amount of hours spent on the laptop) in week two between the two mappings in regard of time spent studying and time spent doing socials activities, purely **because of the different classification of the web-browser**.

Next to that we can conclude that student #2 spends a lot of time on his/her laptop. Using mapping B the student spent *35,8 hours* and *40,8 hours* promoting his/her study value in week 1 and week 2 respectively. When we use mapping A the amount of time spent promoting the study value is even higher. The time spent on study related activities by student #2 is much higher than the amount we estimated at the beginning of this chapter. We do not have a clear explanation for this. Potential factors could be that student #2 spends more time studying than the average student, and that there was an exam week coming up after the second and final week of the experiment. The amount of time students spend studying (using their laptop) could be investigated further in the future with a larger group of students to establish whether the data of the students whom participated in this experiment is representative for the entire student body.

We can conclude that the web-browser is a large factor of uncertainty in the mapping of applications to values. Since it is unreasonable to assume that a student will use different web-browsers for activities that promote different values (e.g. one browser for study, one browser for social networking) like student #1 did, the agent will need more specific data about web-browser activity in the future to more accurately assess what a student is doing.

6.3. PROVIDING FEEDBACK BY USING THE AGENT

As explained in the previous sections the agent requires several types of information in order to reason about a students' behavior and provide feedback. First is the raw activity data which was collected for this experiment, second is a mapping of activities to values which is presented for both students in Table 6.1 & Table 6.3. Finally a student has to set *norms* for him-/herself. In this context a norm represents a simple target in hours spent promoting a certain value. This target can be either a minimum or a maximum. The reason we use the term *norm* is that a norm can represent more than just a static number, and can represent a desirable behavior which can change according to context. In the future the agent can be expanded to handle norms in a more sophisticated manner.
To show an example of the interpretation of activities by the agent we introduce a persona including personal norms and values. We use the norms of this persona as input for the agent.

Name: Penny Grover
Age: 19 years old
Occupation: 1st Year Student Computer Science
Penny is a student who is really dedicated to getting her degree as fast as possible. Since she is an international student she pays a large sum of money to study at the university, which motivates her to study quite a lot. She doesn't have a large interest in student life and is not part of any student society.
Values: Academic Success (0.9); Social Activities (0.1)
Norms Penny wants to set:
Minimum of 6 hours of studying per day.
Minimum of 2 hours using IntelliJ per day.
Maximum of 1 hour of social activities per day.

Table 6.5, Table 6.6 & Table 6.7 show what type of messages the agent would send as feedback to the student based on the data of the test students. In this scenario the agent sends feedback whenever a minimum / maximum target is reached, or when the student is halfway towards reaching a target. For instance: Penny has set a norm of reaching 6 hours of studying per day, thus the agent will send a message after 3 & 6 hours of study related activities each (calender) day.

Table 6.5 shows feedback messages that the agent would send based on the behavior of student #1, and Table 6.6 & Table 6.7 show this for student #2. In Table 6.6 the web-browser is classified as an activity that solely promotes the study value, and in Table 6.7 the web-browser is classified as an activity that promotes both study and social values equally. It can be concluded that the difference between the resulting tables is quite large. This shows that the classification of the web-browser has a rather large effect on the type and accuracy of the feedback that the student receives. *This is a threat to the usefulness of the agent.* The classification of the web-browser is not a problem for student #1 because he/she used two different web browsers during the experiment period. However, since it is unreasonable to expect users to use two different web-browser to facilitate the use of a support agent, a useful agent requires more detailed information about activity within the web-browser in order to define a more fine grained and accurate mapping of the web-browser to different values. A minimum amount of information that could be collected within the web-browser is top level domains. However, this information

Date	3h. Study	6h. Study	0.5h. IntelliJ	1h. IntelliJ	1h. Social	2h. Social
Mon 25-03-2019	✓	✗	✗	✗	✓	✗
Tue 26-03-2019	✓	✗	✗	✗	✗	✗
Wed 27-03-2019	✓	✓	✗	✗	✗	✗
Thu 28-03-2019	✓	✓	✗	✗	✗	✗
Fri 29-03-2019	✓	✗	✓	✓	✗	✗
Sat 30-03-2019	✓	✗	✗	✗	✓	✓
Sun 31-03-2019	✓	✓	✗	✗	✓	✓
Mon 01-04-2019	✓	✓	✗	✗	✓	✗
Tue 02-04-2019	✓	✓	✓	✗	✓	✗
Wed 03-04-2019	✓	✗	✗	✗	✗	✗
Thu 04-04-2019	✓	✓	✗	✗	✗	✗
Fri 05-04-2019	✓	✓	✗	✗	✗	✗
Sat 06-04-2019	✓	✓	✗	✗	✗	✗
Sun 07-04-2019	✗	✗	✗	✗	✓	✓

Table 6.5: Norm flags triggered by student #1. The columns represent (half of) the norms set by our persona Penny. Penny has a set a norm for a minimum of 6 hours of studying per day, thus the agent will send a message after 3 hours, and after the full 6 hours. Penny also has norms for using IntelliJ for a minimum of 1 hour per day, and for spending a maximum of 2 hours per day on social activities.

is more privacy sensitive than the data that was collected for this experiment. This is a challenge because sensitive data must be handled carefully, and because the students whom participated in the workshop described in chapter 4 both indicated to be hesitant about sharing more data than just application names and time stamps.
Therefore we propose the following: **there should be a clear distinction between data that is (privacy) sensitive, and data that is not**. Based on this distinction the agent will be able to analyse more sensitive data in real time, but this data will not be stored. For instance, when the agent receives information about a web-domain that is being visited it will map that to the corresponding values if such a mapping is available. The agent will then store the values which are affected by the use of this web-domain and discard the rest of the information. This ensures the privacy of the student.

RQ 2.3 *What data & knowledge does an agent need to successfully implement its functionalities?*

The agent can start to implement its functionalities by using data that contains only the names of applications and time stamps related to their usage. However the mapping of a web-browser to appropriate values is an issue because the web-browser can be used for many different things. The web-browser is used a lot so an error in the mapping of this application has a quite large impact on the accuracy of the agent. Therefore it is crucial to implement some form of in web-browser tracking for the agent to successfully assess the behavior of a student. The accuracy of the assessment can be improved with additional data, but this has much less impact than web-browser tracking.

Date	3h. Study	6h. Study	0.5h. IntelliJ	1h. IntelliJ	1h. Social	2h. Social
Mon 01-04-2019	✓	✓	✓	✗	✗	✗
Tue 02-04-2019	✓	✓	✗	✗	✗	✗
Wed 03-04-2019	✓	✓	✗	✗	✗	✗
Thu 04-04-2019	✓	✗	✗	✗	✗	✗
Fri 05-04-2019	✓	✓	✗	✗	✗	✗
Sat 06-04-2019	✓	✓	✗	✗	✗	✗
Sun 07-04-2019	✓	✓	✗	✗	✗	✗
Mon 08-04-2019	✓	✓	✗	✗	✗	✗
Tue 09-04-2019	✓	✓	✗	✗	✗	✗
Wed 10-04-2019	✓	✓	✓	✓	✗	✗
Thu 11-04-2019	✓	✗	✗	✗	✗	✗
Fri 12-04-2019	✓	✓	✗	✗	✗	✗
Sat 13-04-2019	✓	✓	✗	✗	✗	✗
Sun 14-04-2019	✓	✓	✓	✗	✗	✗

Table 6.6: Norm flags triggered by student #2, using mapping A (assuming using the web-browser is completely study related). The columns represent (half of) the norms set by our persona Penny. Penny has a set a norm for a minimum of 6 hours of studying per day, thus the agent will send a message after 3 hours, and after the full 6 hours. Penny also has norms for using IntelliJ for a minimum of 1 hour per day, and for spending a maximum of 2 hours per day on social activities.

Date	3h. Study	6h. Study	0.5h. IntelliJ	1h. IntelliJ	1h. Social	2h. Social
Mon 01-04-2019	✓	✗	✓	✗	✓	✓
Tue 02-04-2019	✓	✓	✗	✗	✓	✓
Wed 03-04-2019	✓	✗	✗	✗	✓	✓
Thu 04-04-2019	✓	✗	✗	✗	✓	✓
Fri 05-04-2019	✓	✗	✗	✗	✓	✓
Sat 06-04-2019	✓	✗	✗	✗	✓	✓
Sun 07-04-2019	✓	✗	✗	✗	✓	✓
Mon 08-04-2019	✓	✗	✗	✗	✓	✓
Tue 09-04-2019	✓	✓	✗	✗	✓	✓
Wed 10-04-2019	✓	✓	✓	✓	✓	✓
Thu 11-04-2019	✓	✗	✗	✗	✓	✓
Fri 12-04-2019	✓	✗	✗	✗	✓	✓
Sat 13-04-2019	✓	✗	✗	✗	✓	✓
Sun 14-04-2019	✓	✓	✓	✗	✓	✓

Table 6.7: Norm flags triggered by student #2, using mapping B (assuming using the web-browser is half study related, and half social). The columns represent (half of) the norms set by our persona Penny. Penny has a set a norm for a minimum of 6 hours of studying per day, thus the agent will send a message after 3 hours, and after the full 6 hours. Penny also has norms for using IntelliJ for a minimum of 1 hour per day, and for spending a maximum of 2 hours per day on social activities.

RQ 2.4 *How can we address the privacy concerns that arise when student data is collected?*

To improve the capability of the agent to fulfil its tasks, more data needs to be collected than for this prototype. To address privacy concerns that may arise, there should be a clear distinction between raw data that is tracked, and classified data that stored and/or shared. The stored data must not contain any (privacy) sensitive information.

6.4. CONCLUSION

Now that we have answered all of the sub-questions by using the results from the focus group with academic counsellors (chapter 3), the workshop with first year students (chapter 4), and the experiment with our PoC agent in this chapter we can formulate an answer to the main research question:

RQ 2 *What functionalities should a useful, privacy aware, self-study support system entail?*
A minimum, useful, support system should create a feedback loop between itself and the user. The system needs to establish what the user is doing at any given time, and assess whether this activity aligns with the (long term) goals of the user. The system needs to provide feedback to the user based on its findings. In order to establish what the user is doing the system requires a minimum amount of information about applications used and web-browser activity. To assess whether the applications the user is using contribute to the goals of the user context is required. In this prototype *norms & values* are used as contextual information. The collection of more data or the addition of more context information could lead to better performance of the support system, but also leads to more privacy concerns. To address this the system should make a clear distinction. Data that is stored and/or shared should be anonymous and contain no sensitive information.

In the next chapter we will discuss our findings and the answers to our research questions. Next to that we will highlight the shortcomings of our research along with several recommendations for future work.

7

Discussion & Recommendations

In this chapter we will discuss the results of the research conducted in this thesis. We will do this revisiting main research questions and analysing our findings. We will conclude this chapter with our recommendations for future work related to self-study support agents.

7.1. Research Results

We started this thesis by posing several research questions, and we have found answers to these questions by investigating existing tools and research, consulting academic counsellors and students, and by conducting an experiment with a Proof of Concept (PoC) agent. While all of the people whom participated in the interviews and the experiment are adequate representatives of the academic counsellors and first year Computer Science & Engineering students respectively, the number of participants in all of these activities was low. Therefore none of the results we found can be treated as representative of all academic counsellors or the entire student body. Rather, the results we found form a PoC that can be used as a starting point for further research. We will now discuss the answers we found to the research questions introduced in section 1.1.

Research Question 1: ***What are existing applications & techniques that can provide insight and help with study behavior?***

We found there are ample applications available to track activities on both computers and (smart)phones. Most applications are based on tracking the applications users use, and for how long users use these applications. The goal and target audience differs per tool, but some of them can be used as a starting point or dependency for a self-study support agent. We showed this by used an existing application, ActivityWatch [11], as basis for our PoC in this thesis. The potential of activity trackers is not limited to just data collection regarding application names and time-stamps. More metrics are available in activity trackers. For instance web-browser data about web-domains, or window titles could be used as input for an agent in the future.
Next to the activity trackers, we also found numerous applications and research projects that focus on assisting with self-study in various ways [14, 15, 21, 36]. Especially STELA[1] is a project

[1] https://stela-project.org/

that is related to the domain of supporting students with self-management by providing feedback. These techniques could be investigated more when the feedback channels of the agent are explored further in future work.

Research Question 2: ***What functionalities should a useful, privacy aware, self-study support system entail?***

To find an answer to this question we conducted a focus group with several domain experts (the academic counsellors), organised workshops with students, and constructed and tested a PoC for a self-study support agent. In doing so we found that the concept of a self-study support agent is definitely feasible, and that both academic counsellors and students we spoke with are positive about the potential of such an agent. The self-study support agent should support students with activities, and should not have a direct connection with the academic counsellors, according to the counsellors and students we interviewed.

The PoC agent we implemented and tested uses a minimal amount of data gathered by an activity tracker: application names, and time stamps. We found that it is possible to analyse whether a student is studying or doing something else by mapping an application to *values* [27–31]. However, since the mapping of the applications to values was assigned in an arbitrary fashion, this causes issues for the reliability of the agent. Especially the web-browser is a rather large factor of uncertainty as mentioned in section 6.2. The two participants in the data tracking experiment spent *72%* and *63%* of their time in a web-browser respectively. We have seen that if the participant does not take measures to improve the accuracy of the mapping of applications to values, such as using different web-browsers for different activities, the current way of mapping applications to values is inadequate. Since it is unreasonable to expect students to use multiple web-browsers on a daily basis, the accuracy of the mapping needs to be improved by other means.

The accuracy of the mapping from applications to values aside, we did see that the agent is able to provide feedback to students based on their activity data and the *norms* they set. The agent is capable of keeping track of which individual applications are used as well as the amount of time students use applications that contribute to specific values. This is promising because this combination of activities, values, and norms forms the core of the agent.

The types and amount of feedback which the agent provides to students can be adapted and improved in the future. This is also applicable to the type and amount of data that is provided to the agent by an activity tracker. The tracking of additional data could lead to privacy concerns. Therefore we propose to map sensitive data to values and storing those. This way sensitive data can be analysed and then discarded to ensure the privacy of students.

7.2. RECOMMENDATIONS FOR FUTURE WORK

Since the work that was done for this thesis has resulted in a PoC there is still a lot which needs be improved before a fully functional self-study support agent can be released. In this section will address several topics which could be researched further.

7.2.1. ANALYSING ADDITIONAL INFORMATION SOURCES

It was shown that the agent is capable of reasoning regarding student behavior based on limited information about student activities and relatively little norms and values. However the reasoning and accuracy of the agent could be improved with more data. The activity data collected from both students whom participated in the data collection experiment shows that both of them spent more than 60% of the time using their laptop in a web-browser. As mentioned in the previous section, because of the versatility of the web-browser it is almost impossible

to accurately map the web-browser to values that are promoted with additional contextual information. This can be improved by collecting more information about activities within the web-browser. However this raises privacy concerns, and students may not be willing to share this information if there are no adequate measures in place to ensure the privacy of students, as was discussed in chapter 4.

We recommend researching the benefit of tracking in web-browser activity & windows to increase the accuracy of mapping applications used to promote values. Next to this, additional devices could also be utilised to further improve the tracking of student behaviour. The use of (smart)phones could be tracked, as well as time spent on assignments without using laptops or (smart)phones.

7.2.2. ADVANCING AGENT REASONING

In the prototype, the reasoning of the agent is rather simple. Activity data is processed and feedback is based on simple addition of activities and promotion of specific values. The agent could use forms of pattern recognition to identify how long a student is spending behind the computer in one sitting, or promoting a specific value, and support (more) healthy behavior and frequent brakes. Additionally the agent could learn (individual) user behavior and provide more customised feedback over time.

7.2.3. IMPROVING FEEDBACK CHANNELS

As another potential improvement, the agent could utilise multiple feedback channels. For instance: pop-messages, a dashboard and periodic (e-mail) reports. It could be researched further which modalities of feedback work best. This might differ per student. During the interviews, both the academic counsellors and students indicated that they would like a combination of feedback methods to be available. It could be researched which types of feedback are most effective and appreciated by students. Feedback on the study behaviour of students could also be improved from the start by using the LASSI test that was mentioned by the academic counsellors [34, 35], and by researching how this test was integrated in an analytics dashboard as part of the STELA project [36]. This could provide the agent with more contextual information about students when they start using the tool.

7.2.4. STUDENT TIME INVESTMENT

This thesis is situated in field of Computer Science & Engineering. A recommendation outside that field regarding student time investment is discussed in the remainder of this paragraph. Based on the guidelines set by the TU Delft regarding self-study [2], and our analysis of the roster we estimated students to spent between and 18-26 hours on their laptop every week. However, after the experiment we concluded that both students spent a lot more time (studying) on their laptop than expected. Next to that our PoC agent does not take into account weekdays, and expects students to work the same amount of time every single day. We recommend researching the (self-)study behaviour of a larger group of student, for and extended period of time. In doing so it could be established what the average amount of time a student spends (self-)studying is, and how this is distributed across the days of the week. Another thing we suspect it that the amount of hours a student spends studying will increase towards the end of a quarter, this factor could also be investigated in a longer term tracking experiment.

[2] https://www.tudelft.nl/en/education/programmes/bachelors/cse/bachelor-of-computer-science-and-engineering/degree-programme/

8

Conclusion

In this thesis we researched the feasibility of using an intelligent agent to support first year Computer Science & Engineering (CSE) students with self-study. We showed the feasibility of such a *self-study support* agent by answering our main research questions and designing, implementing and verifying a prototype agent.

To structure our research we studied existing work and created research questions related to the properties an intelligent agent would need in order to support a student in a useful way. To to answer the research questions questions we:

- Conducted a focus group with academic counsellors (chapter 3).
- Organised a workshop with first year CSE students (chapter 4).
- Implemented and tested a prototype agent as a Proof of Concept (chapter 5).
- Tracked and analysed the activity of two students using our prototype (chapter 6).

We gathered information about student issues and needs from the academic counsellors, whom currently support struggling students. We found the agent should provide feedback to students based on targets they set themselves beforehand, and that students should get a periodic overviews of their activities. Based on the focus group with the counsellors we created an initial design of the interactions the agent would support.

Subsequently we organised two one-on-one workshops in which we created a triangle of interactions between agent, student and counsellors together with the participants. The resulting designs are very similar to the design that was created after the focus group with the academic counsellors. Both the academic counsellors and the students whom participated indicated they appreciated a possible use for an intelligent agent that supports students with self-study.

We created a prototype of a system that can collect activity related data from students, and subsequently process and analyse it. By collecting and analysing the data of two first year students we have shown that it is possible to create an agent that provides feedback on the behavior of a student by collecting as little as application names and time stamps. The prototype can provide feedback by combining the tracked data of the student with a mapping of applications to values that are promoted, and norms set by the user.

Our analysis shows that even though the agent is able to provide feedback to the user with little information, the system has a rather large error margin. This is mainly due to the fact that the web-browser is a large *black box*, because it can be used for many different purposes.

Both students whom participated in the data tracking experiment used the web-browser for more than 60% of the time they spent on their computer. The agent will need more detailed information about web-browser activity (such as top-level web-domains visited) to create a more reliable mapping of activity to affected values.

Collecting (sensitive) data about students leads to privacy concerns and should be addressed in the design of the final application. There should be a division between data tracked in real time and data stored by the agent to create overviews and to share with the academic counsellor. Sensitive information should be mapped to values and the original data should be deleted.

A

Initial Mock-up of Student & Agent interaction

A.1. Scenario

In this subsection we will illustrate the potential of using a Socially Adaptive Electronic Partner (SAEP) by illustrating a scenario in which a SAEP might aid a student and academic counsellor in their process of improving the study results of the student. We start by introducing two personas for this scenario and outlining their goals:

A.1.1. The Student

Name: Jim Huizenga
Age: 20 years old
Occupation: Student Computer Science
Values: Health; academic success; social life
Jim is a student that is having trouble studying, he has trouble concentrating and doesn't get a lot of work done even though he knows that he should spend more time studying effectively. Jim already failed several courses so at this point he is under a lot of pressure: he needs to pass almost all of the remaining courses in order to pass the year. This is why Jim is interested in contacting the academic counsellor and finding out what is holding him back and how he can study more effectively.

A.1.2. THE COUNSELLOR

Name: Anne Troost
Age: 37 years old
Occupation: Academic Counsellor Computer Science
Anne has been an academic counsellor for eight years and has helped many students with problems over the years. However sometimes it is difficult for her to diagnose what is actually bothering students, or to provide them with a structure that helps them performing better on their own. Often students realise that they should study in a more effective and structural manner but lack the discipline to actually do this by themselves. Anne thinks that a SAEP could help students study more effectively and help her gain more insight at the same time.

A.1.3. THE SCENARIO

The student and the academic counsellor can, after they have established that the SAEP is useful and that the student is willing to share his/her private data, collaborate during a meeting to define **norms** for a SAEP that can in turn aid them in the analysis of the students behaviour. *The norms represent desired behaviour, which is in this case the use of applications that the student requires for his/her studies for a certain period of time. (Non)compliance with these norms will promote and/or demote certain values that the student has.*

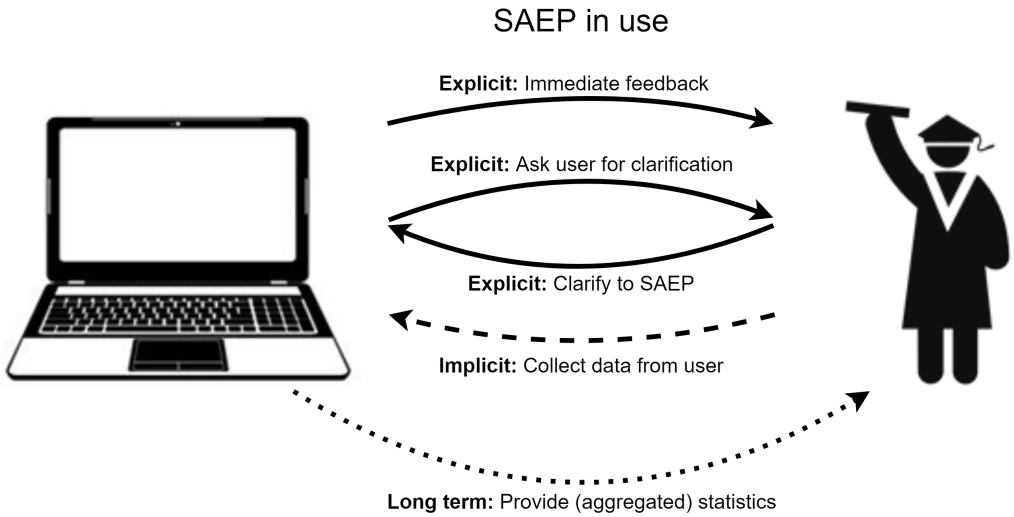

Figure A.1: General flow of setup and usage of a SAEP for a student with the help of the academic counsellor.

This scenario starts when the counsellor and the student meet together and talk about what the student needs help with. They can think of norms together, optionally with the use of a template, and decide what courses or activities the student needs help with. In this case Jim has trouble getting any work done at all, so they want SAEP to help Jim with spending his time effectively. Once they have completed charting the things that Jim should do using Anna's previous experience, the templates, and Jim's course schedule, Jim installs an app on this phone and PC that the SAEP can use to collect data and communicate with Jim. Because of the apps that Jim installed the SAEP can now monitor what activities Jim is doing and deduce whether

Jim is spending his time in a desirable fashion. As can be seen in figure A.1, the SAEP can provide immediate feedback to Jim when he is doing well or poor, so Jim can work on his productivity. The SAEP can also share the statistics with Anne in digests so she can review the data to improve her understanding of the student and discuss the progress with Jim. This way the SAEP can help Jim function better, and improve the academic counsellors insight in the personal situation of individual students.

B

Material Used for Expert Interview Academic Counsellors

The following appending contains the questionnaire and scenario used in the expert interview with the academic counsellors of computer science & engineering. The results of the questionnaire have not been used as further input for this study as the sample size is too small. Instead the questionnaire has been used as a discussion starter during the expert interview. Since all of the counsellors that participated in the expert group are fluent Dutch speakers, the material used in the interview has been written in Dutch.

B.1. QUESTIONNAIRE

1. Ik ben op dit moment als studieadviseur in staat om studenten adequaat te helpen met hun studie activiteiten.
2. Ik heb op dit moment als studieadviseur voldoende middelen om een student bij te staan buiten gesprekken met de student om.
3. Studenten die bij mij op gesprek komen kunnen mij zelf voldoende vertellen over hun studeer gedrag, om hier effectief feedback op te kunnen geven.
4. Als studieadviseur heb ik behoefte aan aanvullende informatie over de studie effectiviteit van een student.
5. Studenten zijn in het algemeen in staat om zelf in te schatten of hun studeer gedrag goed of slecht is.
6. Ik denk als studieadviseur dat een computerprogramma studenten kan helpen met effectief studeren.
7. Ik denk als studieadviseur dat een computerprogramma mij kan helpen om meer inzicht te krijgen in het studeer gedrag van studenten.
8. Ik heb als studieadviseur op dit moment voldoende contactmomenten met hulpbehoevende studenten.
9. Ik denk als studieadviseur dat een computerprogramma mij kan helpen om de tijd tussen contactmomenten met een student te overbruggen
10. Het maken van een studieplan samen met een student is nuttig om de student te helpen met studeren.
11. Ik maak wanneer studenten problemen hebben met studeren altijd een studieplan samen met de student.

	Helemaal oneens			Neutraal			Helemaal eens
Q1	☐	☐	☐	☐	☐	☐	☐
Q2	☐	☐	☐	☐	☐	☐	☐
Q3	☐	☐	☐	☐	☐	☐	☐
Q4	☐	☐	☐	☐	☐	☐	☐
Q5	☐	☐	☐	☐	☐	☐	☐
Q6	☐	☐	☐	☐	☐	☐	☐
Q7	☐	☐	☐	☐	☐	☐	☐
Q8	☐	☐	☐	☐	☐	☐	☐
Q9	☐	☐	☐	☐	☐	☐	☐
Q10	☐	☐	☐	☐	☐	☐	☐
Q11	☐	☐	☐	☐	☐	☐	☐

B.2. PERSONAS

B.2.1. DE STUDENT

Naam: Jim Huizenga
Leeftijd: 20 years old
Geslacht: M
Nationaliteit: Nederlandse
Beroep: Student Computer Science
Belanrijke Values: Gezondheid, academisch succes, sociale interactie

Jim is een student die problemen heeft met studeren, hij kan zich niet zo goed concentreren en krijgt niet genoeg werk verzet op een dag. Hij realiseert zich dat hij effectiever moet studeren. Jim heeft al een aantal vakken niet gehaald, en staat nu onder druk: hij moet al zijn vakken halen om nog aan de eis voor het BSA te voldoen. Hierdoor is Jim gedreven om contact op te nemens met de studieadviseur. Hij hoopt dat de studieadviseur hem kan helpen met plannen en effectief studeren.

B.2.2. DE STUDIEADVISEUR

Naam: Anne Troost
Leeftijd: 37 years old
Geslacht: V
Nationaliteit: Nederlandse
Beroep: studieadviseur Computer Science

Anne is al een jaar of acht een studieadviseur en heeft in die tijd al een flink aantal studenten met problemen geholpen. Echter, soms is het lastig voor haar om exact vast te stellen wat het probleem is van een student of om de student effectief te helpen, omdat dit veelal ook vanuit de student zelf moet komen. Sommige studenten hebben problemen met structuur en studeren niet effectief of niet genoeg. De studenten realiseren zich vaak wel dat dit anders moet, maar hebben problemen om dit te bewerkstelligen, ook Anne kan ze hier maar in beperte mate mee helpen. Anne heeft recentelijk kennis gemaakt met het concept van de SAEP die studenten kan helpen met studeren en is aan het experimenteren met hoe ze het beste studenten kan bijstaan met de hulp van een SAEP.

B.3. SCENARIO

B.3.1. HET EERSTE GESPREK

Nadat Jim zich heeft gerealiseerd dat hij een probleem heeft met effectief studeren en wil hier iets aan doens omdat hij studeren belangrijk vindt voor een betere toekomst. Hierom neemt hij contact op met de studieadviseur. Hij gaat op gesprek bij Anne en samen maken ze een studieplan voor Jim. Om Jim te ondersteunen met zijn studiedoelen bespreken ze het gebruik van een SAEP. Anne legt Jim uit dat een SAEP kan helpen door zijn activiteiten te monitoren en feedback te geven op zijn studiegedrag, ook kan Anne de data die verzameld is door de SAEP gebruiken om hem beter van dienst te zijn bij een eventueel vervolggesprek. Jim heeft zelf de keuze om te bepalen of hij zijn persoonlijke data wil delen met Anne of niet. Nadat hij heeft nagedacht over het gebruik van een SAEP gaat hij akkoord: het lijkt hem een interessante tool. Anne en Jim gaan samen aan de slag om de afspraken voor de SAEP op te stellen. Hiervoor moeten ze in een wizard invoeren voor welke vakken Jim de SAEP wil gebruiken en wat voor programma's hij daarvoor gaat gebruiken. Ook moeten ze invoeren hoeveel uur Jim per vak per week op met zijn laptop wil studeren. Daarnaast kan Jim ook aangeven welke andere applicaties belangrijk voor hem zijn, en waarom. Jim geeft aan dat hij het fijn vindt om af en toe Facebook en WhatsApp te gebruiken omdat hij waarde hecht aan sociaal contact. Hier kan de SAEP dan rekening mee houden. Nadat ze samen het setup process hebben doorlopen installeert Jim de SAEP applicatie op zijn laptop. Hij kan nu aan de slag.

B.3.2. WERKEN MET DE SAEP

Jim gaat studeren met de SAEP aan. Nadat Jim een tijd heeft geprogrammeerd voor een vak in IntelliJ, opent hij Prolog. Hij krijgt een notificatie van zijn SAEP, dit keer met een vraag: Dit programma zit nog niet in de knowledge base, is dit programma nuttig voor een vak? Jim kan met nee antwoorden of een vak selecteren. Vanaf nu weet de SAEP dat Prolog een nuttig programma is, en zal dit ook als zodanig registreren. Figuur B.1 laat een visuele representatie van de interacties tussen de student en de SAEP zien voor dit scenario.

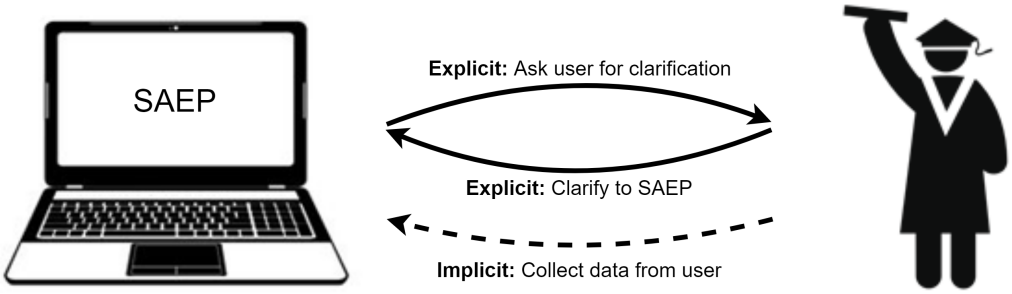

Figure B.1: De SAEP vraagt om verduidelijking van de student.

De feedback die de SAEP geeft op het studeergedrag van de student kan op verschillende manieren worden vormgegeven. In de onderstaande subsections zijn drie verschillende scenarios van feedback geven geschetst.

PASSIEVE SAEP

Jim gaat studeren met de SAEP aan. Op het moment dat Jim wordt afgeleid wordt dit door de SAEP geregistreerd, maar Jim merkt daar niets van. Ook als hij gedurende langere tijd zich laat afleiden krijgt hij geen melding daarover. Aan het einde van de week krijgt Jim een overzicht te zien waarin hij kan zien wat zijn effectiviteit was in de afgelopen week. Op basis van dit overzicht kan Jim zelf conclusies trekken over zijn studie effectiviteit en eventueel zijn gedrag aanpassen in de week daarna.
Jim kan zelf bepalen of hij het overzicht dat hij krijgt wil delen met de studieadviseur. Die kan hem aanvullend persoonlijk advies geven in een vervolggesprek. Figuur B.2 laat een visuele representatie van de interacties tussen de student en de SAEP zien voor dit scenario.

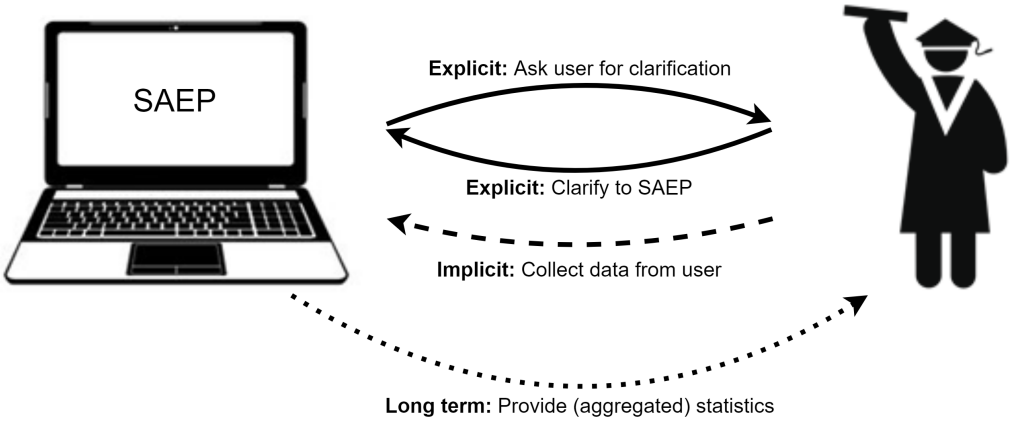

Figure B.2: De SAEP geeft feedback in een passieve rol.

ACTIEF COACHENDE SAEP

Jim gaat studeren met de SAEP aan. Op het moment dat Jim wordt afgeleid door een berichtje van een vriend op WhatsApp, houdt SAEP er rekening mee dat dit ook belangrijk is voor Jim, dus krijgt hij geen bericht van de SAEP. Echter als Jim daarna fimpjes op YouTube begint te kijken krijgt hij direcht een notificatie van zijn SAEP: kan hij zich niet beter bezighouden met studeren? Doordat Jim vrijwel direct wordt geconfronteerd met het feit dat hij is afgeleid gaat hij snel weer aan de slag. Nadat Jim een tijd effectief heeft gewerkt krijgt hij een bericht van de SAEP: hij krijgt complimenten voor het feit dat hij zich niet heeft laten afleiden, en kan nu even pauze houden. Op deze manier houdt de SAEP constant in de gaten of Jim effectief werkt en ook op tijd pauze neemt. Dit helpt hem om vandaf het eerste moment effectiever te werken en niet te verslappen in zijn houding.
Omdat de SAEP Jim actief van feedback voorziet hoeft hij niet stelselmatig afspraken te maken met de studieadviseur. Hij kan met behulp van de SAEP zelf doelen stellen en daarmee zijn gedrag wijzigen. FiguurB.3 laat een visuele representatie van de interacties tussen de student en de SAEP zien voor dit scenario.

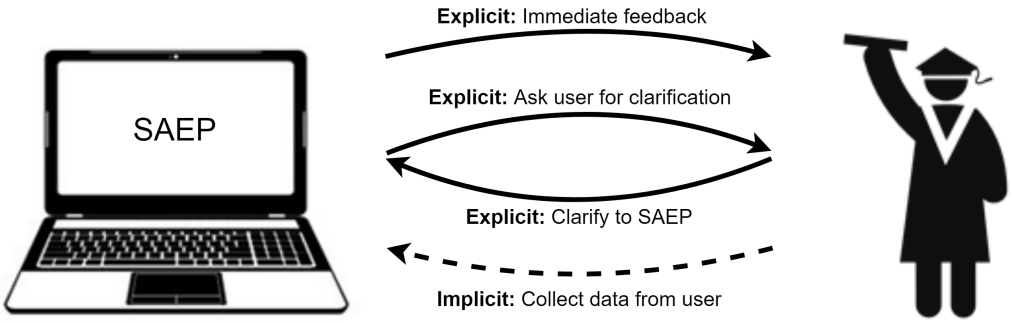

Figure B.3: De SAEP geeft feedback in een actieve rol.

COACHING VIA DE STUDIEADVISEUR

Jim gaat studeren met de SAEP aan. Op het moment dat Jim wordt afgeleid wordt dit door de SAEP geregistreerd, maar Jim merkt daar niets van. De SAEP houdt echter wel bij dat Jim is afgeleid en deelt dit met de studieadviseur die bij kan houden hoe het met Jim gaat in zijn/haar eigen overzicht, dat continue wordt bijgewerkt.
Wanneer de studieadviseur denkt dat Jim wel wat extra coaching kan gebruiken, of juist dat het heel erg goed gaat met Jim kan deze contact met hem opnemen om dit met Jim te bespreken. Doordat de studieadviseur de data van Jim kan inzien krijgt deze meer inzicht in wat er zich afspeelt bij de student, en kan deze zelf bepalen wanneer het juiste moment is om contact met Jim op te nemen om zijn studie effectiviteit te evalueren. Figuur B.4 laat een visuele representatie van de interacties tussen de student en de SAEP zien voor dit scenario. Figuur B.5 laat een mockup zien van het overzicht dat de studieadviseur te zien krijgt.

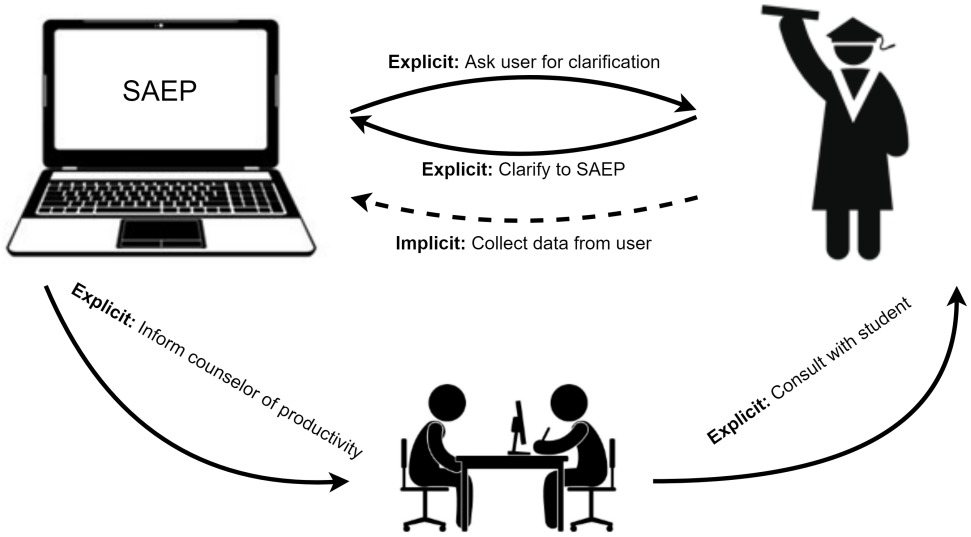

Figure B.4: De SAEP geeft feedback via de studieadviseur.

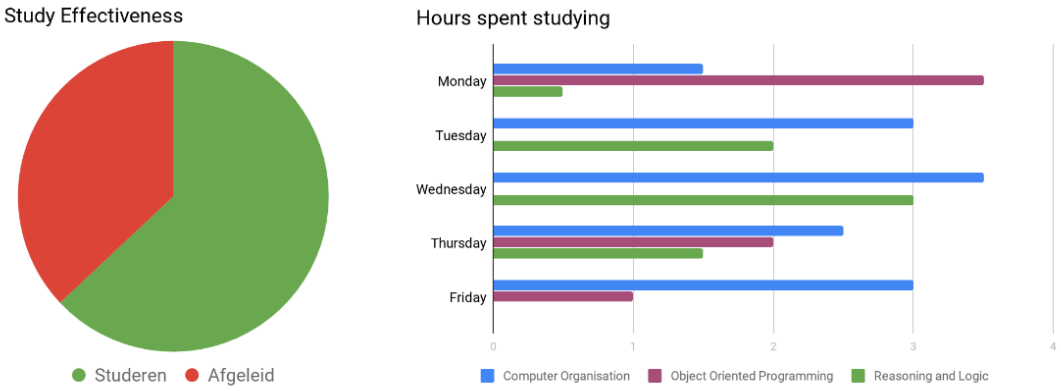

Figure B.5: Een voorbeeld van wat de studieadviseur te zien krijgt.

C

Material Created During Interview CSE Students

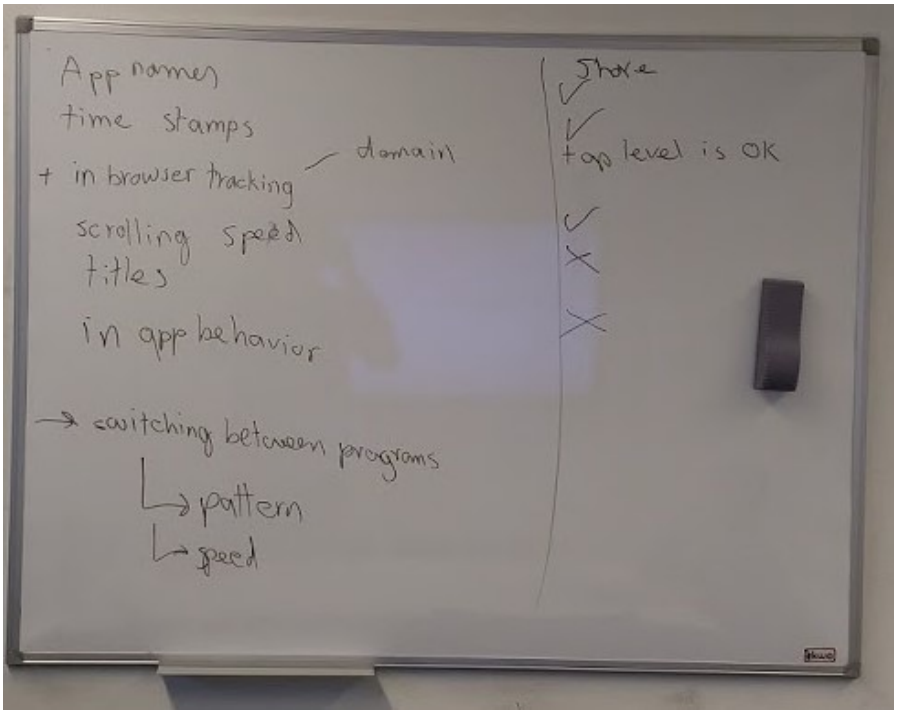

Figure C.1: Suggestions related to activity tracking; student #1

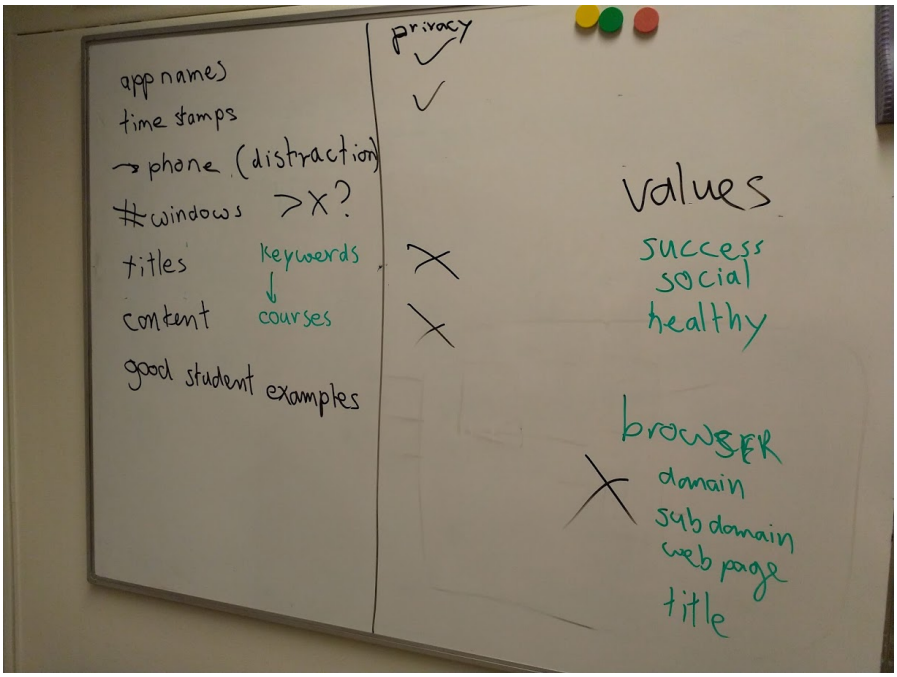

Figure C.2: Suggestions related to activity tracking; student #2

D

Ethical Accountability

As part of this project three different experiments have been conducted. Two of these experiments were forms interviews, of which audio has been recorded for transcription. The third experiment was focused on real world data collection from first year students, and involved them making use of a tool on their laptop. The next sections will explicate the goal of each of the experiments and the measures that have been taken to ensure that all collected data is handled with appropriate care.

D.1. Focus Group with Academic Counsellors

The focus group with the academic counsellor was an experiment focused on collecting more information about the potential uses of agents that support students from the perspective of domain experts. Audio was recorded during this experiment to allow for transcription afterwards. Because the audio recording contains information that may allow for personal identification of the participants, the experiment has been submitted to and approved by the EEMCS board of ethics. Subsequently all participants of the experiment have been asked to sign an informed consent form before the start of the experiment. Below the summary of the application that has been submitted to the board of ethics and the informed consent form used for this study have been included.

Delft University of Technology
ETHICS REVIEW CHECKLIST FOR HUMAN RESEARCH
(Version 10.10.2017)

This checklist should be completed for every research study that involves human participants and should be submitted before potential participants are approached to take part in your research study.

In this checklist we will ask for additional information if need be. Please attach this as an Annex to the application.

Please upload the documents (go to this page for instructions).

Thank you and please check our website for guidelines, forms, best practices, meeting dates of the HREC, etc.

I. Basic Data

Project title:	**Socially Adaptive Electronic Partners that Help Students Study Effectively**
Name(s) of researcher(s):	**T.A.R. Overklift Vaupel Klein**
Research period (planning)	**October 30th 2018**
E-mail contact person	**t.a.r.overkliftvaupelklein@student.tudelft.nl**
Faculty/Dept.	**Intelligent Systems, Computer Science**
Position researcher(s):[1]	**MSc CSE Student**
Name of supervisor (if applicable):	**M. B. van Riemsdijk**
Role of supervisor (if applicable):	**Assistant professor**

II. A) Summary Research

I would like to interview a group of 3 academic counsellors of the EEMCS faculty for my thesis project about the development of socially adaptive electronic partners for students. These partners will aid students, and academic counsellors, in the future to help students improve their effectiveness in regard to studying. The setup of the experiment is a focus group with the 3 counsellors in which several scenarios and statements revolving around the (projected) use of these electronic partners will be discussed. No details regarding actual students will be discussed.

There will be notes taken during the discussion and the audio of the meeting will recorded. After the meeting the audio will be transcribed, and after this the audio will be destroyed.

B) Risk assessment

The main risk of this study is the audio recording that will be taken during the interview. The audio recording will be transcribed after the interview, and be destroyed once this is complete.
Any personal information regarding the counsellors, such as their name will not be shared beyond the research team or published in the thesis.
In compliance with the regulations surrounding identifiable data, an informed consent form, that will be filled in before the experiment takes place, has been attached to this submission.

[1] For example: student, PhD, post-doc

Consent Form for *Focus Group SAEPs for Students*

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study information dated 30-10-2018, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	○	○
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	○	○
I understand that taking part in the focus group involves notes being taken and audio being recorded for the duration of the focus group. Additionally, this audio will be (partially) transcribed and used as input for the study. The audio recording will be destroyed after the study has been completed.	○	○
Use of the information in the study		
I understand that information I provide will be used for the thesis report and presentation associated with this study.	○	○
I understand that personal information collected about me that can identify me, such as [e.g. my name or where I live], will not be shared beyond the study team.	○	○

Signatures

_____	_____	_____
Name of participant	Signature	Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_____	_____	_____
Researcher name	Signature	Date

Study contact details for further information:

Thomas Overklift, +31(0)6[redacted], t.a.r.overkliftvaupelklein@student.tudelft.nl

D.2. WORKSHOP WITH CSE STUDENTS

The workshop with first year CSE students was an experiment focused on collecting more information about the potential uses of agents that support students from the perspective of potential users. Audio was recorded during this experiment to allow for transcription afterwards. Because the audio recording contains information that may allow for personal identification of the participants, the experiment has been submitted to and approved by the EEMCS board of ethics. Subsequently all participants of the experiment have been asked to sign an informed consent form before the start of the experiment. Below the summary of the application that has been submitted to the board of ethics and the informed consent form used for this study have been included.

Delft University of Technology
ETHICS REVIEW CHECKLIST FOR HUMAN RESEARCH
(Version 10.10.2017)

This checklist should be completed for every research study that involves human participants and should be submitted before potential participants are approached to take part in your research study.

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Please upload the documents (go to this page for instructions).

Thank you and please check our website for guidelines, forms, best practices, meeting dates of the HREC, etc.

I. Basic Data

Project title:	**Socially Adaptive Electronic Partners that Help Students Study Effectively**
Name(s) of researcher(s):	**T.A.R. Overklift Vaupel Klein**
Research period (planning)	**3rd Week of December 2018**
E-mail contact person	**t.a.r.overkliftvaupelklein@student.tudelft.nl**
Faculty/Dept.	**Intelligent Systems, Computer Science**
Position researcher(s):[1]	**MSc CSE Student**
Name of supervisor (if applicable):	**M. B. van Riemsdijk**
Role of supervisor (if applicable):	**Assistant professor**

II. A) Summary Research

I would like to organise a participatory design workshop with 12 first year Computer Science students for my thesis project about the development of socially adaptive electronic partners for students. These partners will aid students, and academic counsellors, in the future to help students improve their effectiveness in regard to studying.
The setup of the experiment is a workshop with the 12 students in which they will brainstorm about possible interactions between students, academic counsellors and electronic partners in groups of 3-4 students. The students will be asked to create diagram in which they draw the interactions on a large sheet of paper. Afterwards the groups will be asked to present the design they came up with and explain the interactions they created.

There will be notes taken during the design and presentations of the designs by the students. The diagrams created by the students during the workshop will be saved and included in the thesis.
The audio of the presentations will also be recorded. After the workshop the audio will be transcribed in order to explain the designs that the students created in the thesis. After this the audio will be destroyed.

[1] For example: student, PhD, post-doc

B) Risk assessment

The main risk of this study is the audio recording that will be taken during the workshop. The audio recording will be transcribed after the workshop, and be destroyed once this is complete.

The diagrams that are created by the students are completely anonymous as they are not required to provide any personal information.

Any personal information regarding the students, such as their name will not be shared beyond the research team or published in the thesis.

In compliance with the regulations surrounding identifiable data, an informed consent form, that will be filled in before the experiment takes place, has been attached to this submission.

Consent Form for *Participatory Design Workshop SAEPs for Students*

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study information dated 17-12-2018, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	○	○
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	○	○
I understand that taking part in the workshop involves notes being taken and audio being recorded for the duration of the workshop. Additionally, this audio will be (partially) transcribed and used as input for the study. The audio recording will be destroyed after the study has been completed.	○	○
Use of the information in the study		
I understand that information I provide will be used for the thesis report and presentation associated with this study.	○	○
I understand that taking part in the workshop involves the creation of a diagram together with several fellow students. This diagram will be used for the study and will be published as a part of the thesis related to this study.	○	○
I understand that personal information collected about me that can identify me, such as [e.g. my name or where I live], will not be shared beyond the study team.	○	○

Signatures

_____	_____	_____
Name of participant	Signature	Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_____	_____	_____
Researcher name	Signature	Date

Study contact details for further information:

Thomas Overklift, +31(0)6[redacted], t.a.r.overkliftvaupelklein@student.tudelft.nl

D.3. ACTIVITY TRACKING EXPERIMENT

The activity tracking experiment with first year CSE students was an experiment focused on collecting some real data about the activity of first year students. Several things were tracked for this experiment: applications used (e.g. chrome.exe), time stamps, usage duration, and whether the user was away from keyboard (AFK). More personal data such as window titles and web browser activities have been excluded from this experiment due to privacy concerns. The setup for this experiment has been approved by the board of ethics after it had been submitted along side a data management plan (DMP). According to this plan all data collected from the students will be stored and archived in a project repository of the Interactive Intelligence group. All processed student data that has been processed will remain anonymous.
All participants of this experiment have been asked to sign an informed consent form before the start of the experiment. Below the summary of the application that has been submitted to the board of ethics and the informed consent form used for this study have been included.

Delft University of Technology
ETHICS REVIEW CHECKLIST FOR HUMAN RESEARCH
(Version 10.10.2017)

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Please upload the documents (go to this page for instructions).

Thank you and please check our website for guidelines, forms, best practices, meeting dates of the HREC, etc.

I. Basic Data

Project title:	**Socially Adaptive Electronic Partners that Help Students Study Effectively**
Name(s) of researcher(s):	**T.A.R. Overklift Vaupel Klein**
Research period (planning)	**Februari 2019**
E-mail contact person	**t.a.r.overkliftvaupelklein@student.tudelft.nl**
Faculty/Dept.	**Intelligent Systems, Computer Science**
Position researcher(s):[1]	**MSc CSE Student**
Name of supervisor (if applicable):	**M.L. Tielman**
Role of supervisor (if applicable):	**Postdoctoral Researcher**

II. A) Summary Research

I would like to ask a group of first year Computer Science students to install an activity tracker on their laptop and run this on their device for a period of two weeks. This is part of my thesis project about the development of socially adaptive electronic partners for students. These partners will aid students, and academic counsellors, in the future to help students improve their effectiveness in regard to studying.
The setup of the experiment is that the student installs the tool, which subsequently tracks what a student is doing. The tool can track: whether the student is AFK or not, what application a student is using, and for how long. More detailed information such as window titles or any information from inside applications will not be collected. The users will be able to see what data has been collected at any time and can remove this if they want. They can also turn off the tool at any time if they wish. The data that is collected will not be shared (automatically) in any way.
I will ask the students to manually export a file with data at the end of the experiment, which they can review and subsequently share with me if they are still ok with that.

The data collected about the students will be completely anonymous since I will only receive application names such as "chrome.exe" or "eclipse.exe" paired with several time stamps. The information gained from this experiment will be used to see whether it is feasible to automatically reason about the study habits of a student by a SAEP.

[1] For example: student, PhD, post-doc

As part of this experiment we plan to offer students a small compensation for the time they invest in using the tool. We have checked the "no" box for #10, because we believe this is very reasonable. Students will receive the reward if they participate in the experiment, regardless of what data they decide to share at the end of the experiment. Because of this there is no incentive for students to share more data than they are comfortable with because of an additional reward.

B) Risk assessment

The main risk of this study is the data that is exported from the tool. This could be personal if the student uses very specific applications (normal application instances would be "chrome.exe" or "winword.exe"). This risk is regulated by the fact that students can see what data is being collected about them in a graphical overview, and in the exported file (which will be in .json) and remove the data if they don't want to share it.

Study Information about *Activity Tracking for SAEPs for Students*

The study "Activity Tracking for Socially Adaptive Electronic Partners (SAEPs) for Students" has the goal to collect the information about the applications used by the target participants, first year Computer Science and Engineering students.

- The participants will be asked to install an activity tracker on their laptop and run this on their device for a period of two weeks. The setup of the experiment is that the student installs the tool, which subsequently tracks what a student is doing. The tool can track: whether the participant is AFK or not, what application a participant is using, and for how long. More detailed information such as window titles or any information from inside applications will not be collected.

- The participants will be able to see what data has been collected about him/her at any time during the experiment and can remove this if they want. They can also turn off the tracker at any time if they wish. The data that is collected will not be shared automatically in any way.

- After the test period, the participants will have to manually export a file with, which they can review and subsequently share with the researchers if they (still) consent to the processing of this data.

- The data collected about the participants will be processed anonymously, and does not contain any sensitive information as only application names such as "chrome.exe" or "eclipse.exe" paired with several time stamps will be tracked. The information gained from this experiment will be used to see whether it is feasible to automatically reason about the study habits of a student by a SAEP.

- The main risk of this study is the data that is exported from the tracker. This could be personal if the participant uses very specific applications. This risk is regulated by the fact that participants can see what data is being collected about them in a graphical overview, and in the exported file (which will be in .json). The participants can remove any data they don't want to share it, or can withhold from sharing any data at all.

- The participant has the right to refuse to share his or her data, and stop the use of the tracking to at any point. The participant has the right to request his or her data to be deleted after it has been shared.

- As part of this experiment a small compensation is offered to participants for the time they invest in using the tool. Participants will receive the reward if they participate in the experiment, regardless of what data they decide to share at the end of the experiment. Because of this there is no incentive for students to share more data than they are comfortable with because of an additional reward.

- The raw data collected during this study will be retained until the thesis related to this experiment is completed (Q2 2019). The processed, anonymous, data will be published in the TU Delft repository as part of the master thesis.

Consent Form for *Activity Tracking for SAEPs for Students*

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study information dated 28-02-2019, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	○	○
I consent voluntarily to be a participant in this study and understand that I can refuse to share any data and I can withdraw from the study at any time, without having to give a reason.	○	○
I understand that taking part in the study involves running an application on my computer that will track which applications I use, and for how long, for an extended period of time.	○	○
Use of the information in the study		
I understand that data I provide will be used for the thesis report and presentation associated with this study on an anonymous basis.	○	○
I understand that personal information collected about me that can identify me, such as [e.g. my name, email or where I live], will not be shared beyond the study team.	○	○
I understand that the data I provide will be processed and published anonymously in the repository of the TU Delft as part of a master thesis.	○	○

Signatures

_____	_____	_____
Name of participant	Signature	Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_____	_____	_____
Researcher name	Signature	Date

Study contact details for further information:

Thomas Overklift, +31(0)6[redacted], t.a.r.overkliftvaupelklein@student.tudelft.nl

E

Linear Temporal Logic

Linear Temporal Logic introduces the concept of time in a logical calculus and thus accommodates for proofs that show safety and liveness properties [43, 44]. However this type of logic is not sufficient when it comes to quantitative reasoning. For instance the GOAL agent can have a belief about a certain norm `appMaxNorm(Appname, Duration)`, that will cause an action to be executed when the agent has the belief that the usage of application *Appname* exceeds amount *Duration*. The notion of $X >$ *Duration* cannot be expressed with linear temporal logic as there is no concept of ordinance. In the next section it is shown that LTL can still be used to prove the processing of observations by the agent when quantitative reasoning is left out.

E.1. Example proofs using Linear Temporal Logic

In this section we show that LTL can still be used to verify certain properties of the GOAL agents. We use the definition for linear temporal logic introduced in chapter two of the book *Formal Methods for Discrete-Time Dynamical Systems* [46]:

Definition - Propositional Temporal Logic

$$\phi = \top \mid o \mid \phi_1 \wedge \phi_2 \mid \neg\phi \mid \bigcirc \phi \mid \phi_1 U \phi_2$$

Where:

- ϕ is a formula over a set of observations O.
- $o \in O$.
- $\bigcirc$ is a temporal operator that represents *next*.
- U is a temporal operator that represents *until*.
- $\Diamond$ represents *eventually*
- $\Box$ represents *always* .

Scenario: basic observation of activity - Given the following:

- an activity percept a (in GOAL: *activity(X,Y,Z)*)
- an usage belief b (in GOAL: *appUsage(X,Y,Z)*)
- an application $A \in O$ that forms the domain of these observations, so that $a, b \in A \in O$

We can define the following clause: $(a \rightarrow \Diamond b) \wedge (\neg a \rightarrow \neg b)$ which can be read as: *an activity percept implies a usage belief, and no activity percept implies no usage belief*. Note that $(\neg a \rightarrow \neg \Box b)$ is not correct as a percept a can be observed at a later stage and will then lead to the belief b.

Scenario: enforcement of a norm - Given the following:

- an activity percept a (in GOAL: *activity(X,Y,Z)*)
- an usage belief b (in GOAL: *appUsage(X,Y,Z)*)
- a norm c (in GOAL: *appNorm(X,Y)*)
- an action d (sending a message)
- an application $A \in O$ that forms the domain of these observations, so that $a, b, C \in A \in O$

We can define the following clause: $(b \wedge c) \rightarrow \Diamond d)$ which can be read as: *a usage belief combined with a norm related to the same application will lead to a message being sent eventually*. Note that this derivation does not include the notion of duration, which is a limitation that has been discussed in the previous section.

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