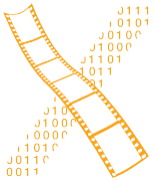

Chair for Computer Science 10 (Media Computing and Human-Computer Interaction)

RWTH AACHEN UNIVERSITY

Why are you using a screwdriver? Exploring virtual process documentation assistance agents in the maker community

Master's Thesis
submitted to the
Media Computing Group
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Registration date: 08.12.2020
Submission date: 28.05.2021

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Abstract

In the community of makers documentation is of great importance. Documentation can help people to find information about how to build projects or inspire them to create new ones. It can also help makerspaces to present projects being build there in order to gather new sponsors for the lab. But they are still missing the tools to write good documentation and sometimes also the knowledge of how to write a good documentation. In this thesis we suggest and test a possible solution to both of the problems using virtual embodied agents as documentation assistants. The assistant should appear on a screen and ask questions to the makers to collect all data needed to automatically generate a documentation.

We conducted a study to answer the question whether such a system can be a useful tool to support makers in their documentation process without distracting them too much from working such that it becomes annoying. Additionally we wanted to find out if the system can improve the makers knowledge on how to write a good documentation in order to enable beginners to rebuild a project.
We split the study into two rounds. In the first round, expert makers had to build a project and write a documentation for it. In the second round another group of experts used a simulation of the documentation assistant. Between those rounds we gave the experts documentation of the first round to beginner users to investigate what their documentations were missing and how we had to improve the documentation that we simulated to be generated by the assistance system.

We found that the annoyance factor was lower than we expected for both rounds, but did not have a high difference between the two rounds. Also the system made the documentation process a lot faster and clearly made the users more aware of the contents of a good documentation. The usefulness of an animated agent in our study cannot be confirmed as users did not look at them most of the time.

Überblick

In der Maker Community ist Dokumentation von großer Bedeutung. Dokumentation kann Menschen helfen, Informationen darüber zu finden, wie man Projekte baut, oder sie dazu inspirieren, neue Projekte zu erstellen. Sie kann auch Makerspaces dabei helfen, die dort gebauten Projekte zu präsentieren, um neue Sponsoren für das Lab zu gewinnen. Allerdings fehlt es an Tools zur Erstellung guter Dokumentation und manchmal fehlt auch das Wissen, wie man eine gute Dokumentation schreibt. In dieser Arbeit wird eine mögliche Lösung für beide Probleme vorgeschlagen und getestet, indem virtuell verkörperte Agenten als Dokumentationsassistenten eingesetzt werden. Der Assistent sollte auf einem Bildschirm erscheinen und den Makern Fragen stellen, um alle Daten zu sammeln, die für die Dokumentation benötigt werden.

Wir haben eine Studie durchgeführt, um die Frage zu beantworten, ob ein solches System ein nützliches Werkzeug sein kann, um die Maker in ihrem Dokumentationsprozess zu unterstützen, ohne sie zu sehr dabei zu nerven. Zusätzlich wollten wir herausfinden, ob das System das Wissen der Maker über den Inhalt einer guten Dokumentation für Anfänger verbessern kann.
Wir haben die Studie in zwei Runden aufgeteilt. In der ersten Runde mussten erfahrene Maker ein Projekt nachbauen und eine Dokumentation dazu schreiben. In der zweiten Runde verwendete eine andere Gruppe von Experten eine Simulation des Assistenten. Zwischen diesen Runden gaben wir die Dokumentationen der ersten Runde an Anfänger, um zu untersuchen, was ihren Dokumentationen fehlte und wie wir die vom Assistenzsystem simulierte Dokumentation verbessern mussten.

Wir stellten fest, dass der Nervigkeitsfaktor bei beiden Runden niedriger war als wir erwartet hatten, aber es gab keinen großen Unterschied zwischen den beiden Runden. Außerdem hat das System den Dokumentationsprozess deutlich beschleunigt und den Benutzern die Inhalte einer guten Dokumentation bewusster gemacht. Die Nützlichkeit eines animierten Agenten kann in unserer Studie nicht bestätigt werden, da die Benutzer ihn nur wenig angeschaut haben.

Acknowledgements

I would like to thank my thesis advisor Marcel Lahaye for the idea of this thesis topic, the constant support and helpful suggestions during the creation of my thesis.

I also want to thank Prof. Dr. Borchers and Prof. Schroeder for examining my thesis.

Another big thank you belongs to my 24 study participants for taking the time and effort to participate in the study and also my girlfriend for helping me deliver and collect the Arduino Kits to and from the participants.

Conventions

Throughout this thesis we use the following conventions.

Text conventions

Definitions of technical terms or short excursus are set off in coloured boxes.

EXCURSUS:
Excursus are detailed discussions of a particular point in a book, usually in an appendix, or digressions in a written text.

Definition:
Excursus

The whole thesis is written in Canadian English.

Chapter 1

Introduction

In this work we want to investigate the usefulness of a documentation assistant system for makerspaces using a virtual embodied agent.
To create a common understanding of the used terminology, the following definitions of terms are provided.

MAKERSPACE/FABLAB:
Makerspaces or FabLabs, are places that are open to the public and free to use. People can build their own products based on their own ideas here. The rooms provide tools like laser cutters, 3d printers, CNC mills or electrical soldering irons[Theresa Willingham, 2015].

Definition: *Makerspace/FabLab*

MAKER/TINKERER:
A maker, also known as tinkerer is a person who actively engages in makerspaces or FabLabs or builds similar projects at home.

Definition: *Maker/Tinkerer*

VIRTUAL EMBODIED AGENT:
An embodied agent is an intelligent agent that interacts with the environment through its body[Fu et al., 2019]

Definition: *Virtual embodied agent*

In the community of makers documentation is of great importance. It can help people to find information about how to build projects or inspire them to create new projects. It

Documentation is shown to be important in the maker community

can also help makerspaces to present projects being build there in order to gather new funding agencies for the lab. In a survey around makerspaces by [Kylie Peppler, 2015] the makerspaces agreed that documentation practices are important to them. However fourteen percent of them stated that they are in need of tools that can help with the documentation process without distracting the makers from their work. As stated by [Kraut et al., 2011], people often do not like documenting their work as much as they enjoy building it. He also wrote that: "It is axiomatic that people won't be able to contribute what a community needs unless they are aware of those needs and have the skills and resources to contribute them"[Kraut et al., 2011]. In summary, people do not only lack the tools to easily document their work, but also the knowledge on how to write good documentation.

Makers need tools and knowledge to write documentation

Virtual embodied agents as possible solution to those problems

In this thesis we suggest and test a possible solution to both of these problems using virtual embodied agents as documentation assistants. To this end, the assistant should appear on a screen and ask questions to the makers to collect all data needed to automatically generate a documentation.

First, we introduce current solutions and tools for documentation as well as known examples of virtual agents. Then we discuss the criteria a virtual agent needs to fulfill in terms of visual appearance and perceived personality. We also explain which general requirements the system must fulfill in order to be motivating, easy to use, and to bridge the knowledge gap between expert makers and beginner documentation readers. In chapter 3 we define agents to be used by the system in terms of their appearance and personality. We explain the design and setup of a user study and provide the results in chapter 4. The study uses a Wizard of Oz scenario to simulate the virtual agents animations and speech using face tracking and lip-syncing. We prepared a project documentation before the study and simulate that the system does the generation. The process of using the agent system is then compared to the process of writing a documentation themselves. We evaluate the results of the user study in chapter 5. In the last chapter, we summarize the work and suggest future directions.

Chapter 2

Related work

2.1 Current solutions of documentation tools

The idea of building tools for documentation purposes in makerspaces is not new. A survey by [Kylie Peppler, 2015] shows that documentation is of high importance to the maker community. They "reported a general need for higher-quality equipment and easy-to-use tools" [Kylie Peppler, 2015]. In this chapter, we introduce some already existing maker documentation tools.

Protospace Utrecht's Check-in, Check-out Kiosk System

In 2011 Protospace Utrechts introduced a "kiosk", which is a stand next to the door of the FabLab, where users had to check in and out providing information about themselves and their work [Määttä and Troxler, 2011].

FabAcademy launched a competition for documentation tools

Another approach was started by the FabAcademy in 2019. They introduced a competition called the docubot challenge[1]. The aim was to build a documentation tool that could take and store photos and videos. As the making process usually requires both hands, the device was required to work with speech processing. The participants were Mak-

[1] https://wikifactory.com/+distributed-hardware-hackathon/docubot

Figure 2.1: Documentation Assistant Lamp [5]

The teams developed different solutions to control taking photos and videos and help to take notes

erspace Madrid[2], Trouble Maker Shenzhen[3] and PumpingStation: One from Chicago[4]. The team from Madrid developed a software to control photos and videos taken for documentation. The software forces the user to describe the next picture or video before being able to shoot it. The Shenzhen team developed a device that can take pictures and save it on a computer with simple voice commands. Additionally makers can let the device record their speech and it will turn it into text and also save it on the computer. The third team from Chicago built a button which gives a command to a phone to start recording voice messages and pictures. This challenge focused on devices to help the user to take pictures, videos and collect notes. This is a common approach in this area.

Kevin Cheng developed the Documentation Assistant Lamp

Kevin Cheng developed a documentation lamp [6] shown

[2] https://wikifactory.com/+distributed-hardware-hackathon/madrid-docubot-team
[3] https://wikifactory.com/+distributed-hardware-hackathon/docubot-shenzhenteam
[4] https://pumpingstationone.org/
[6] http://archive.fabacademy.org/archives/2016/fablabtaipei/students/103/final/index.html

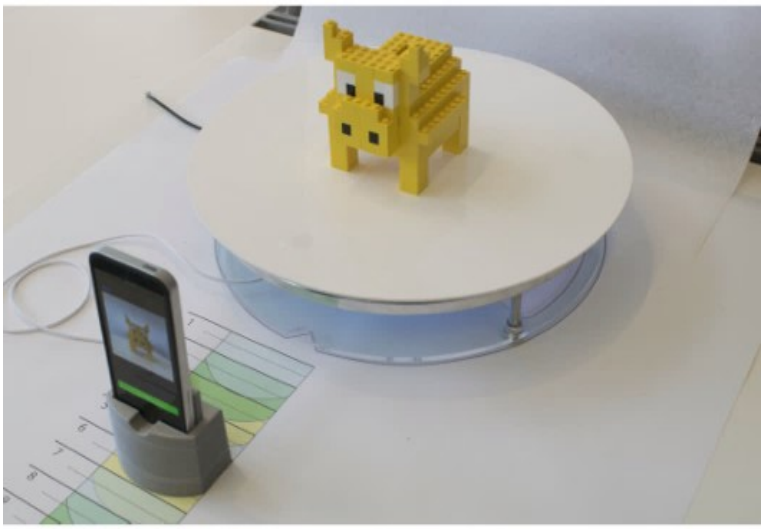

Figure 2.2: Spin - a photo turntable system [Tseng and Resnick, 2016]

in Figure 2.1 in 2016. In place of a light bulb, the lamp is equipped with a phone which records the maker's process. The lamp can be moved in five degrees of freedom through a mobile app and is intended to be able to follow the makers movement in the future. This is only one of many ideas that makers had to avoid having to hold their phone while making.

The lamp has a camera instead of a light bulb to follow the makers actions

Keune et al. [Anna Keune, 2015] summarize a variety of possibilities to mount phones and tablets with simple and cheap solutions. For example, a tablet can simply be put into the right position by mounting it into an egg carton and a phone with a back cover built from Lego can be attached to anything else lego pieces can be glued to.

There are different setups to position phones and tablets

Tiffany Tseng and Mitchel Resnick developed a system that is also picture-based, but instead of assisting the process documentation, it is used to document the end product. They created Spin, a "photo turntable system for creating animated documentation of tangible design projects" [Tseng and Resnick, 2016]. The table shown in Figure 2.2 is specifically designed to encourage children to document their work. They can connect their phone to the table, place

Spin - the photo turntable system to record documentation videos

their project on spin and use an app to start the capturing process. The application then produces a three second animation which shows the turning project.

Document while doing tool to collect notes and pictures during making

However, documenting after making brings up different difficulties. Makers might forget important steps and problems that occur during the process will likely not be documented, even though it can help other makers to know about the tricks in difficult situations [Milara et al., 2019]. For this reason, [Milara et al., 2019] developed the documentation application "document-while-doing" that "consists of a mobile phone application, a backend server, and a web application" [Milara et al., 2019]. Makers can collect voice messages and take pictures or notes that will automatically be sent to a server and converted to a website. The results can be edited with a web application after the making process.

A more powerful tool is needed

Although there are a lot of ideas for tools to help makers with their documentation, they all still require the user to write down their steps (or use speech-to-text) and take pictures at the right moments. In this thesis, we therefore choose a different approach to automate the documentation process further.

2.2 Existing Virtual Agents

The use of virtual agents in software is not a new approach. Agents have been used in many different areas like health care, pedagogical, education, or as social companions. In 1997, Lester et al. introduced Herman the bug, a pedagogical agent that gives advice to the players of Design-A-Plant. "In Design-A-Plant, a student's goal in each problem-solving episode is to design a plant that will thrive in a given natural environment"[Lester et al., 1998]. Herman helps the players to grow their plants by providing them with helpful knowledge about botanics.

Herman the bug - pedagogical agent

Steve - educational agent

In the same year, the agent "Steve" was developed by [Johnson and Rickel, 1997]. Similar to Herman, Steve is supposed to help users to learn. In particular, Steve

"helps students learn to perform physical, procedural tasks, such as operating and repairing equipment"[Johnson and Rickel, 1997]. Visually, Steve is only "represented by a head, an upper body, and a hand that can manipulate and point at objects"[Johnson and Rickel, 1997].

Figure 2.3: Healthcare Assistant SimSensei Kiosk - a virtual Agent as health care assistant [DeVault et al., 2014]

Figure 2.4: University Bielefelds FlurMax waving at a visitor [Jung and Kopp, 2003]

SimSensei Kiosk - health care agent

One example of an agent used in health care is the "SimSensei Kiosk". It was developed with the vision to function as a support tool, using existing self-assessment questionnaires. The system was designed to be able to detect indicators for psychological distress and to help with diagnosis[DeVault et al., 2014]. The agent is visually represented as a human interviewer shown in Figure 2.3.

FlurMax - social agent

While agents can be used to help people with learning or assist them with decisions, they can also be fun and social. The university of Bielefeld developed "FlurMax", a social agent living inside a screen in a university hallway. FlurMax can detect visitors with a camera and interact with them. The agent can greet them, wave and say: "Hello, I am Max". FlurMax can recognize gestures like waving and can react to it, by waving back, as illustrated in Figure 2.4. His mood can change from happy to bored, surprised or neutral[Jung and Kopp, 2003].

Clippit - annoying Microsoft agent

Unfortunately not all agents are helpful and causing joy to the users. The most famous example of a failed agent is Microsoft's paperclip Clippit shown in Figure 2.5. It was designed to help the user of Microsoft Office to use the pro-

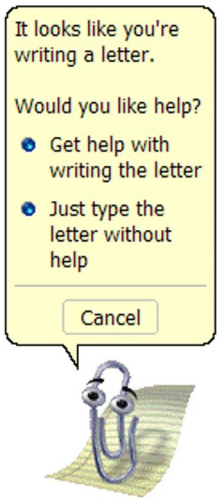

Figure 2.5: Microsoft Assistant - Clippit[Swartz, 2003]

gram correctly. But "While Clippit is a genius about Microsoft Office, he is an idiot about people, especially about handling emotions"[Picard, 2004]. Clippit offered the same advice over and over again and no matter how often users clicked it away, Clippit would give them the same advice repeatedly whenever they started the program. As there was no way to turn the "feature" Clippit off, users got more and more annoyed by it. In 2001 the new version Microsoft Office XP was released and Clippit was finally removed from the program. Although it was only part of the program for four years it remained in the memory of the users. To this day, there are a lot of memes[7], cartoons[8] and funny sketches[9] about this paperclip. Microsoft clearly showed that using virtual agents is not always a good idea and that it requires a lot of sensitivity to create an agent that is likeable, helpful, and does not annoy the user.

Using virtual agents requires sensitivity to not annoy the users

[7] https://www.reddit.com/r/PoliticalHumor/comments/7k7bls/hi_it_looks_like_you_are_trying_to_support_donald/

[8] https://www.youtube.com/watch?v=tu_Pzuwy-JY

[9] https://www.youtube.com/watch?v=EpWbTogEEhg&t=1s

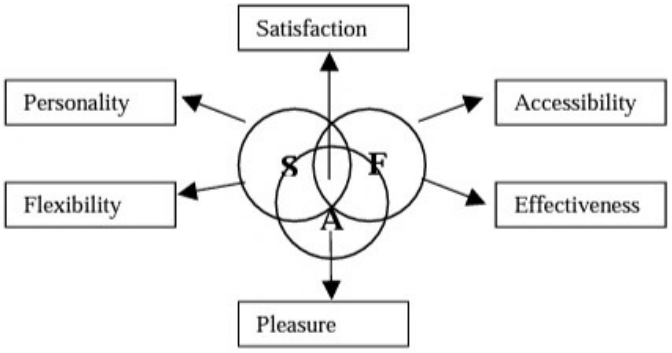

Figure 2.6: The involvement framework by [De Angeli et al., 2002]

2.3 Criteria for agents

The involvement framework describes the user-agent-involvement facets social, functional and aesthetic

The optimal combination results in user satisfaction and is depending on the task, context and user

In order to pick the best agent as documentation assistant, there are many factors to take into consideration. The agent's shape, character, and usability are three general attributes that need to be picked. De Angeli et al. proposed a framework that divided user-agent-involvement into those three categories and named them "social, functional and aesthetic qualities" [De Angeli et al., 2002]. With the right composition of those three values, De Angeli et al. aimed to yield the highest user satisfaction. The optimal amount of each quality "varies according to the task to be executed, the context of interaction, and the nature, or personality, of the end-user" [De Angeli et al., 2002]. This means that there is not one universal agent for all situations and users. The criteria for optimal documentation agents in makerspaces presented in this chapter refer to the involvement framework displayed in Figure 2.6 [De Angeli et al., 2002]. In this framework, the factor aesthetic refers to the appearance of the agent, as discussed in the next subsection 2.3.1, but also to the appearance of the system itself. The appearance of the system, as well as the functionality factor, which inter-

feres with aesthetics, will be discussed in section 2.4. The social factor comprises the personality of the agent and the interaction with the user. This is considered in section 2.3.2 and 2.3.3. As all three factors are overlapping in the framework, it is important that the aesthetic fits to the personality and the functionality of the system.

2.3.1 Visual appearance of the agent

Aesthetics: different shapes, gender, ages and ethnicities

There are infinite variations to the appearance of an agent. Agents can be humans, animals, mythical creatures or even objects. They can have all sorts of genders or no gender at all. They can be young, old or something in between and they can belong to different ethnic groups. Physical appearance is part of the aesthetic dimension in the involvement framework and has a high influence on how we perceive the agent. The aesthetic dimension aims for pleasure which can be received if the appearance is enjoyable. Appearance is also the first impression we get of an agent and as [Asch, 1946] found out, the information we gain about another person first, plays more into our picture of the person than what we learn later. Therefore it is important to pick the visual appearance of our virtual agent carefully.

Appearance as a first impression counts more in peoples picture of a person than what they learn later

Attractive agents are rated more positive on other attributes while unattractive agents are rated less positive

One important factor for the agent's shape is attractiveness. [Wilson, 2002] found that users enjoy the experience with virtual agents less when they are not attractive. Less attractive agents even lead to relating the system with other negative traits. In contrast, if the agent is attractive, the 'halo effect' could occur. This effect describes the phenomenon that if a person or agent has one positive attribute, other values will automatically be rated higher [Grcic, 2008]. Thus, the more attractive the agent is, the better ratings it may get for its overall personality. This effect is also visible in the users' views on the Microsoft agent Clippy. The Microsoft agent in the shape of a paperclip was generally perceived as very annoying and not very helpful. A study by [Xiao et al., 2004] showed that users preferred the assistant in the shape of a dog or a cat and had less negative thoughts about those, even though their behaviour is identical to Clippy's. While attractiveness of the agent is important,

it is difficult to measure. According to the media equation [Reeves and Nass, 1996] humans treat computers like real humans. It has been shown that this equation counts for virtual agents as well[Rickenberg and Reeves, 2000, Hoffmann et al., 2009]. Therefore psychological human-human interaction theories can be applied to the interaction between humans and virtual agents. [Solomon et al., 2013] found that there are six different types of good looks, which are highly depending on the context they are seen in. They explained those looks with examples of fashion models. Importantly, that attractiveness is rated differently depending on the context. In a study by [Little et al., 2001] users had to rate the attractiveness of faces from pictures. The study showed that the users found those pictures most attractive that showed the highest similarity with their own face. Another factor contributing to attractiveness is the presence of smile. [Reis, 1990] found that smiling people appear more attractive and competent than not smiling people. More on the effect of smiling is explained in section 2.3.3.

According to the media equation and further research humans treat virtual agents like humans

Attractiveness depends on the context

People voted attractiveness highest when people looked similar to themselves

Smiling is attractive

When it comes to realism of the agent's shape, it is important to take into account the Uncanny Valley Effect. This effect was first described in 1970 by Masahiro Mori [Stein and Ohler, 2017]. Mori found that robots that look a lot like humans can cause a feeling of uncanniness if they are not behaving like we expect humans to behave. The same effect was found for animal characters [Schwind et al., 2018]. Hence, if the robot or avatar looks very human- or animal-like, it needs to behave authentically. If this is not possible, it is best to choose a less realistic appearance such that users expect less realistic behaviour. Facial expressions are crucial attributes of behaviour. They can easily lead to uncanniness if they are not congruent with the agent's appearance [Schwind et al., 2018]. The facial expression of stylized agents was shown to be easier to detect than the facial expression of realistic humanoid agents [Adamo et al., 2019].

The Uncanny Valley Effect for realistic looking robots

Uncanny Valley Effect was also shown for virtual animals

Due to gender stereotypes, the gender expression of the agent influences the perception of its competences. Since certain careers are thought of as typically male or female, people with the corresponding gender expression are perceived as more competent in the field. In Baylor "it was

The agent's gender influences perception due to stereotypes

found that male agents were more influential than female agents in promoting the usefulness of engineering" [Baylor, 2009] and according to another study by [Ernst and Herm-Stapelberg, 2020] virtual assistants with male voices were perceived more competent than those with female voices. Since the user group of makerspaces is predominantly male[Bean et al., 2015], it can be assumed that a virtual assistant in a makerspace might be seen as more competent in the shape of a man. Another study by [Gulz et al., 2008] showed that androgynous people were chosen more often as favourite virtual characters than people with an appearance that fits into gender stereotypical categories. As these studies are only based on the appearance of the agents, it is unclear whether the findings apply to agents that act inside a specific context. In fact, the behaviour of the agent has a significant influence on the perception of its competence. [Koda and Maes, 1996] proved this theory by asking people about the intelligence of a caricature dog compared to a caricature male person. Without context, the male person was perceived as more intelligent. This changed when they let each of the two characters play a round of poker before the survey. This suggested to the user that both are capable of playing, meaning that both are intelligent. Hence, the assumed characteristics of the agent based on its gender can be overruled by setting them into the right light. This also applies to the general appearance. Even if the first impression, as mentioned before, weighs more than later information, it is possible to change this bias through behaviour and context.

Androgynous people are preferred over female and male characters

Acting agents can influence their perception of competence

The shape of an agent can vary from humans, over animals to objects. Object like agents (like a block head) were rated less likeable than human- and animal-like agents by [Bailenson et al., 2005]. [Bergmann et al., 2012] suggest to prefer humanoid agents over robot like agents as they communicate more warmth. While [Sträfling et al., 2010] found that an animal agent (a rabbit) received better results in friendliness and was generally rated to be more enjoyable than the humanoid agent, [Koda and Maes, 1996] found that the likeability of virtual agents depends on people's opinion about personification. In their study, nearly half of the participants were not in favour of personification, while the other half liked to have a face on the screen. If they

Object shapes were rated less likeable than humans or animal shapes

People that like personification often feel more comfortable with zoomorphic agents

liked personification, they were also likely to feel comfortable with zoomorphic agents while the other people preferred humanoid agents.

2.3.2 Personality

Social: Personality traits are important to define a consistent character

One important factor in the involvement framework is the personality of the agent: "a stable set of traits defining its overall character" [De Angeli et al., 2002]. A consistent and predictable personality helps the user to easily interact with the system while "unexpected and unpredictable swings between different attitudes can disorient the users and create a strong sense of discomfort"[De Angeli et al., 2002]. Personality is a composition of a variety of character traits. The most widely known model of personality is called "The Big Five" [Digman, 1990]. It is also known as the OCEAN model, an acronym standing for the personality traits *Openness*, *Consciousness*, *Extraversion*, *Agreeableness* and *Neuroticism*. *Neuroticism* can also be described as emotional stability given this formulation is more positive.

The Big Five / OCEAN model can be used to describe personality

The Agency and Communion model is related to the big five

More recently, [Abele et al., 2016] proposed a two factor model consisting of *agency* and *communion* which each can be divided by *assertiveness* and *competence* for *agency* and *warmth* and *morality* for *communion*. This model is derived from the five factor model and describes the four facets with a few precise character traits. The facets *competence* and *warmth* are widely used in research on social interaction with virtual agents or robots [Peters et al., 2017, Nguyen et al., 2015]. The first facet of *agency* is *assertiveness* and is related to the big five factors *neuroticism* and *extraversion* [Abele et al., 2016]. It is associated with attributes like self-confidence, ambitiousness, independence or purposefulness. Agents with high *assertiveness* are perceived to have leadership abilities, never give up easily and stand up under pressure. The second *agency* facet is called *competence* and is related to the big five factor *consciousness*. A competent agent should appear intelligent, efficient, and capable of completing its task. *Warmth* is one of the facets of *communion* and can be compared to the big five factors *agreeableness* and *extraversion*. A warm agent should be car-

The first facet of agency is assertiveness

The other facet of agency is competence

The first facet of communion is warmth

ing and empathetic, it should be friendly and also helpful. The judgment of *warmth* during the evaluation of an agent's personality seems to have more influence on the overall social picture of the agent than its *competence*. It "reflects the importance of assessing other people's intentions before determining their ability to carry out those intentions" [Fiske et al., 2007]. *Warmth* is "likely to improve the level of engagement with the agent" [Clavel et al., 2016]. The last facet of *communion* is *morality* and is associated with being fair, honest and trustworthy.

The other facet of communion is morality

2.3.3 Behaviour

Behaviour is an expression of personality

According to the Cambridge Dictionary[10], personality is shown in behaviour as well as the way we feel and think. Feeling and thinking are both invisible factors and therefore irrelevant for the documentation agent. Behaviour however is a visible attribute and therefore an important factor in displaying the agents personality. Therefore this subsection lays out how personality traits can be expressed through the agent's behaviour.

Gestures influence friendliness and competence of agents

There are multiple studies on the effect of gestures on the agents perceived personality. Those studies show that the "presence of gestures increases the perception of the friendli-ness of a virtual agent" [Randhavane et al., 2019]. In addition gestures can influence the perceived friendliness and competence of the agent [Bergmann et al., 2012]. Both are attributes that we consider to be important for the perception of the agent's personality. However, using gestures is not enough. It is also relevant how gestures are performed. [Randhavane et al., 2019] found in their study that "open gestures are perceived as more friendly, and closed gestures are perceived as less friendly" [Randhavane et al., 2019]. Open gestures were additionally found to be correspond to perceived competence in combination with an upright posture [Peters et al., 2017]. Moreover, "Fiddling was suggested to signal low control and confidence, therefore resulting in low-competence

Open gestures are perceived as friendlier and more competent than closed gestures

Fiddling suggests low competence

[10] https://dictionary.cambridge.org/de/worterbuch/englisch/personality

judgment" [Peters et al., 2017].

Gazing towards a person is friendly and polite

"Gaze is an important aspect of human face to face interaction, and can be used to increase the behavioural plausibility of the virtual characters" [Narang et al., 2016]. An agent also appears friendlier when it gazes towards the user, while it seems less warm when its gaze frequently diverts [Nguyen et al., 2015]. Not looking at the talking person implies impoliteness [Reeves and Nass, 1996]. [Rickenberg and Reeves, 2000] found that users being monitored by virtual characters were more anxious and made more mistakes.

Humour can make the system more enjoyable

Humour can also have negative effects if not used correctly

Humour is shown to create a stronger rapport between user and agent and results in a higher enjoyment of the system [Kulms et al., 2014]. Agents with humour are also perceived as interesting, friendly, pleasant, creative and clever and it mostly influences the traits extraversion and agreeableness [Cann and Calhoun, 2001]. However, humour can also have a negative effect. Users might think that the agent is not serious about the task and is mocking the user [Kulms et al., 2014]. The reaction of the users can vary depending on whether the agent is displaying irony, sarcasm, simple jokes or wordplay and different users might like or dislike certain kinds of humour [Kulms et al., 2014].

Smiling agents are perceived friendlier and warmer

The kind of smiling depends on the context

Smiling of an agent has a major effect and is perceived as more friendly [Cafaro et al., 2012, Ochs and Pelachaud, 2012]. A smiling agent can also cause the users to smile with them [Theonas et al., 2008] and therefore create a fun experience with it. Importantly, the kind of smile in a specific context is essential. A smile that does not fit the context may have a negative effect on the interaction as it could violate social norms [Theonas et al., 2008, Mckeown et al., 2015]. Different types of smiles are polite, amused and embarrassed [Ochs et al., 2017]. Amused smiles lead to a perception of a warm and enjoyable character [Ochs and Pelachaud, 2012]. It is usually evoked by "speech which amuses the listeners and makes them smile" [de Kok and Heylen, 2011]. Embarrassed smiles "are usually situated in areas of long silence and gaze aversion" [de Kok and Heylen, 2011]. The context of polite smiles is less known,

but [de Kok and Heylen, 2011] believe that a polite smile correlates with the speakers smiles. However, [Thibault et al., 2012] show that the perception of smile is also dependent on the culture.

2.4 Motivating the user to use/keep using the system

Functionality: Principles for tools

[Tseng and Resnick, 2016] formulated six design principles for makerspace documentation tools. One of those principles is physical presence of the tools to show that the makerspaces value documentation and to remind makers to document their work. This principle is part of the functional aspect accessibility of the involvement framework [De Angeli et al., 2002]. Functionality does not only mean that it is easy to see or find the tool, but also easy to use it. This counts towards the effectiveness of the tool.

Physical presence of the tool

Natural Language for easy interaction

”Natural Language (NL) appears to be a favourite interaction medium for social artifacts, since users can express their communicative intentions in a spontaneous way (Cassell et al. 2000)” [De Angeli et al., 2002]. Also, the system has to explain the way it works very carefully to make sure the user knows how to handle it. When the user does not share enough information, the system has to ask for it. Asking could of course interrupt the maker while working or even while speaking. ”Interestingly, interruption itself is not the problem; participants in conversations interrupt one another all the time.” [Cassell, 2001]. Cassel pointed out that interrupting the other during a conversation is unproblematic as long as the interruption is motivated by the need for further information or an exclamation of joy about what is being said. Another of Tseng’s rules is ”Make documenting engaging in and of itself” [Tseng and Resnick, 2016]. Using the system should be fun and makers should use the system, because they like using it, not because they are forced to. Forcing the maker to document is still the preferred solution for example in Fab Lab Amersfoort. Makers have to pay a deposit before using the space and only receive it back if they document for the community [Milara et al., 2019]. Celebrating design moments without dis-

Interruption itself is not problematic when motivated by need for information

Documenting should be engaging and fun

Celebrating design moments

tracting too much from the making process is another of the six design principles for documentation tools. Through this strategy, makers receive additional motivation from the system at certain points throughout the process. However, it is crucial that the agent is designed to not be too distracting. Tseng also suggests embracing incompleteness and leaving it to the user how much information the documentation needs to contain. According to Tseng, users should also be empowered to extend the tool. This way the tool can be adapted more flexibly to the user's needs. Lastly the system should be connectable to existing platforms, provide an option to export the documentation to different formats, and give makers the possibility to share their work on the platform of their choice.

Embracing incompleteness

When makers come into initial contact with the system, they need to be convinced that using it is helpful for the community and for themselves. Therefore, [Kraut et al., 2011] created a set of design claims to motivate users to engage in online communities. One of those claims is that initially, users need to be made aware of the need of engagement and why it is important. Then, they need the right tools and access to those. Apparently, it helps to ask the users for engagement individually, instead of only asking the whole community. It is also important who asks for engagement. People with higher status in the community, people that are liked by the maker, people that are similar to the user, and attractive people are the most convincing ones. Additionally, it helps if the users know that other people already complied to the request.

Design claims to motivate users to document

Awareness of need of engagement and having the right tools

Asking people directly

Knowledge that other people documented

2.5 Bridging the knowledge gap

One of the most useful aspects of an automatic documentation generation system is the way it aims to bridge the knowledge gap between the maker and the reader. Makers tend to write less specific information about a process, because they cannot imagine the knowledge state of their readers easily. A maker interviewed by [Tseng and Resnick, 2014] stated: "I can't think I'm doing it for myself. I have to put myself in the mindset of someone approaching it for

It is not easy to think like a beginner

the first time". Reaching this mindset is not an easy task, but an agent system could make it easier. Explaining the process to an agent that imitates a beginner and can also ask follow-up questions might make the users more aware of a beginner's thinking.

Asking a lot, but still allowing incompleteness

However, designing the system to ask for all information needed would break one of the design guidelines of [Tseng and Resnick, 2014], which suggests accepting incompleteness. Therefore it should be left to the user to decide which parts to include in the final documentation. This could for example also be mistakes that happen during the process. Makers can learn from seeing other people's mistakes because it will allow them to avoid making the same ones. "However, in revealing mistakes, one may risk damaging his reputation in the community." [Tseng and Resnick, 2014]. Therefore, it could be advantageous to leave the decision of including or excluding mistakes to the user.

Chapter 3

Designing the agents

3.1 How to display the agent

This section is about the technical solution to display the agent

An assistant for documentation can be provided in various technical forms. It might be a voice assistant, a whole body in the form of a robot, or something in between. One example could be a virtual agent shown on a big screen, on a smaller tablet, on a phone, as a projection on the wall or on the table or even in augmented reality. Each of these solutions comes with advantages and disadvantages. In the next section, we analyze different ways of displaying the agent and their respective upsides and downsides.

Voice assistants do not require to look at them

Voice assistants like Alexa, Siri or Cortana are on the rise and are used frequently by everyday users[Hoy, 2018]. They can be asked for help in any situation without having to interrupt the current actions. In contrast to voice assistants, virtually embodied agents suggest to look at them when they are talking as it is considered impolite not to look at someone while talking[Reeves and Nass, 1996]. Hence, we assume that the maker might feel the need to frequently look at a physically present agent. If the assistant has no shape, this is no problem at all. The user can easily interact with the system without being distracted by its appearance. The aim of the documentation assistant is not only to help the maker be productive, but also to create a fun experience, which might be easier for assistants

Voice assistance are less motivating than personified agents

with a physical shape. "Research confirms that for motivational and effective outcomes in particular, the visual presence of an agent is critical; in other words, a voice alone (human or machine generated) with the same persuasive message is not sufficient" [Baylor, 2009]. For example "it was found that college students who interacted with visible agents reported significantly greater positive motivational outcomes" [Baylor, 2009]. Therefore a voice assistant has practical values, but it is missing a big part of the entertainment factor.

Robots can follow maker, but also get in the way

A socially interactive robot has the ability to walk around on its own. This way, it could follow the maker around autonomously. Robots can even point to specific things when referring to them. This simplifies the communication between the human and robot. However, as robots are physical objects present in the room, they might frequently get in the way and disturb the maker at work.

AR agent do not get in the way, but glasses limit field of view

Augmented reality agents solve the problem of colliding with the robot as they are only a projection. Like a robot, they are able to point at things and move freely on the maker's table. However, since augmented reality requires the makers to wear glasses, it limits the makers field of view and makes working a lot harder and potentially less fun.

Projecting a 2D virtual agent on the table does not limit field of view, but might be disturbing

Augmented reality agents have the problem of limiting the field of view. To overcome this, a similar idea would be the direct projection of an agent on the table or the nearest wall to the maker. This way it could have the same advantages as the AR agent without the problem of limiting the field of view. For this solution, it is likely that multiple projectors are needed to avoid occlusion of the agent as the user is moving around. Nevertheless, we assume that projecting the agent directly to the makers table could potentially be very disturbing as it is always in the maker's field of view.

Portable devices are taken for granted and might be forgotten to bring to another workstation

Virtual agents can also be displayed on screens of phones or tablets. Those can easily be provided to the user and it is possible to take them to wherever they are needed. "The problem with using such ubiquitous devices for documentation is that their presence is frequently taken for granted." [Anna Keune, 2015]. Makers might forget about their pres-

ence and leave it at a workstation when moving on to another. Taking the device with them for every step is not only hard to remember, but also annoying if the maker has to take the current project to other places and needs an extra hand to carry the device. At every station the device would have to be placed in a position where it can be seen without taking up too much of the work space. This process could take a lot of additional time that the maker might not be willing to make. Although phones and tablets can additionally serve as photographing devices, research has shown that "these pictures are oftentimes taken quickly and are blurred, making it difficult to recognize technical or decorative details." [Anna Keune, 2015]. Therefore phones and tablets don't seem to be the perfect solution either.

Big screens are the preferred solution being more in the background

In contrast to portable devices, a big screen mounted to the wall would not require any additional actions of the user. However, the screen might not always be visible to the user depending on the layout of the makerspace. To avoid this problem one could use two screens so one is visible from each location in the makerspace. The agent could simulate to run over to the other screen if it detects that the user is moving. Mirroring one of the screens to the other is another possibility, but this might be distracting and confusing to the user. Displaying the agent on a wall instead of directly on the table might also keep makers from being distracted from the agent, as it is further away and therefore seems to be more in the background. For this thesis big screens are chosen as the most promising solution to display agents, as those are the furthest in the background and therefore we expect those to be the least annoying. Since the COVID-19 situation does not allow for in person studies and we cannot expect every user to have a big screen at home, we will use a computer monitor as a substitute for the screen.

Due to COVID-19 at home study, computer screens are used

3.2 Defining agents

In the following section we define the personality of the agents. Then we introduce and explain three different types of agents. We decided to create an animal, as well as animated humans, since those are the most promising shapes

concluding from section 2.3.1. In order to avoid the uncanny valley effect, as mentioned in section 2.3.1, we choose to display the animated characters in a less realistic cartoon style.

3.2.1 Personality of agents

Agents personality should be a little assertive

We aim for the personality of the agent to be just a little *assertive*. We chose it to be just as self-confident as needed to stand up in front of a stranger and ask for information, but not too much of a leader personality. The maker is supposed to stay in focus and the agent is only an assistant and should therefore act as one.

Agents should be competent in documenting, but not in making

The agents should make clear, that they do not have much *competence* in makerspaces, because the less knowledge they claim to have, the more information they need to understand the process. If they have a lot of making knowledge there is a risk that the user will overestimate how much the agent understands and therefore will not provide precise instructions. In addition, the more the user tells the agent voluntarily, the less questions need to be asked, which we assume leads to a less annoying experience. Nevertheless the system needs to appear competent in writing documentation so the users can trust it immediately to generate a useful documentation.

Agents should be warm and have morality

The agents need to have a lot of *warmth* and *morality* in order to build stronger rapport with the maker. This way the makers are supposed to feel understood and have a fun and friendly experience.

Using open gestures and smiling for a warm and friendly character

Humanoid agents should use open gestures to be perceived as friendly and open, as mentioned in section 2.3.3. Animals cannot use such gestures as those are not natural for them. We expect that friendlier agents are less annoying to the user. This is an important factor, as we assume that asking a lot of questions during the making process can be very stressful and annoying. Therefore we try to compensate the annoyance with a warm and friendly character. The agents need to smile politely during the making process as long as nothing is going wrong. If they detect that something is going wrong, they should change to a sad expression. This decision is based on section 2.3.3. When the agent detects

Agent should take the time to celebrate the user

Figure 3.1: Agent Bella

that a major step of the making process is finished it should take the time to celebrate the user, as this is a design guideline inferred from section 2.4. The agent may use different phrases to express joy and congratulate the user on the success.

3.2.2 Agent Bella - the dog

A dog is chosen as a friendly and faithful character

The dog is interested in making, but does not have making competence

We choose a virtual dog as shown in Figure 3.1, since dogs are perceived as friendly and faithful, character traits that are in line with the personality requirements described in the last section. As said by Nobel Prize winner Konrad Lorenz: "There is no faith that has never yet been broken except that of a truly faithful dog"[1]. The dog tells the makers that she is really interested in making and will probably ask a few questions from time to time. She also tells the makers that she would be happy if they explained to her what they were doing. It is important that she points out that she does not know a lot about making, even if

[1] https://www.goodreads.com/quotes/80252-there-is-no-faith-which-has-never-yet-been-broken

we expect the makers to assume it already. She also has to tell them that a documentation will be generated in the end from the information she collected. We expect that frequent questions might annoy the user a lot. With an agent simulating a pet sitting around while its owner is working, we hope to achieve less annoyance, even though she is asking many questions. The dog is called Bella, as this a very typical name for dogs[2]. The dog is chosen to look as average as possible since [Halberstadt and Rhodes, 2000] found out that average looking dogs are perceived as the most attractive. Therefore we chose a dog with similarity to a Labrador Retriever, which is the most popular dog breed since 1991 according to the American Kennel Club [3]. The American Kennel Club also writes in their official standard for Labrador Retrievers[4], that the official fur colours of Labradors are black, yellow and chocolate. We chose Bella to be yellow, because people tend to assume yellow dogs are friendly while they generally do not with black labs[Walton and Adamson, 2011]. The dog also wears a green collar. According to a colour system of dog collars used in Canada and Australia, green is the signal colour for friendly dogs [5].

It is an average looking Labrador, as average looking dogs are perceived the most attractive

A green collar symbolizes friendly dogs

Bella's exact introduction is this: "Hello, my name is Bella. I like to hang out at makerspaces or FabLabs to watch all the exciting maker projects being built there. I am not an expert in this area, so I am happy if you can tell me as much as you can about your project while you are building it. If I don't understand everything I might have to ask you some questions in between. I hope you don't mind. Alright, are you ready to start?"

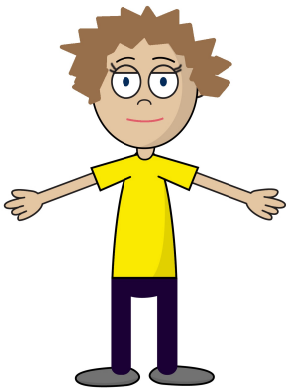

Figure 3.2: Agent Toni

3.2.3 Agent Toni - the human

The agent Toni is a non-binary person

Toni love writing documentation and are excited to help

Toni wear gender neutral clothes

For the human agent we choose a non-binary person named Toni. As shown in section 2.3.1, more androgynous looking people were preferred by users. Additionally, by choosing a non-binary person we are less likely to support unwanted gender stereotypes in any direction. Toni (shown in Figure 3.2) tells a story of them loving to write maker documentations. They are really excited to help the maker to write a documentation and learn more about the project. We chose Toni to wear a gender neutral shirt in yellow, as light colours are more pleasant for users than dark colours[Valdez and Mehrabian, 1994]. Additionally, Toni wears a pair of blue trousers as those are gender neu-

[2] https://www.today.com/pets/these-are-most-popular-dog-names-us-t102267

[3] https://www.cbsnews.com/pictures/best-dog-breeds-most-popular/101/

[4] https://images.akc.org/pdf/breeds/standards/LabradorRetriever.pdf

[5] https://www.dailymail.co.uk/news/article-3182612/The-rainbow-guide-dog-s-softie-Company-produces-different-coloured-collars-pet-s-temperament.html

Toni have brown hair and blue eyes

tral and a common thing to wear for all genders. As usually lighter hair colours are considered more attractive for women and darker hair colours are preferred for male characters [Hinsz et al., 2013], we decided to choose something in the middle for Toni. Therefore they have brown hair. In a study by [Vučinić et al., 2019], blue eyes were rated most attractive for males while brown was rated best for females, directly followed by blue. As blue was the most rated colour overall, Toni's eyes are blue.

Toni's exact introduction is: "Hello, my name is Toni. I like to hang out at makerspaces or FabLabs to watch all the exciting maker projects being built there. I really enjoy writing documentation about maker projects even though I am not an expert in the making area yet. I hope I can learn something and write down a documentation for you. So please tell me as much as you can about your project while you are building it. I might need to ask some questions in between to better understand what you are doing or ask you to take pictures at certain points of the process. In the end I will quickly write your documentation and send it to you. You are then free to change it as you like or leave it as it is. Just see me as your personal assistant for documenting this project. Alright, I am ready to start. Are you?"

3.2.4 Agent Sherlock Holmes and the mysteries of the makerspace

Sherlock Holmes is known for asking a lot of questions

He could provide a less childish environment

He wants to solve a crime and needs the user's help

As a third agent we choose Sherlock Holmes as shown in Figure 3.3. Since he is a famous detective, asking questions is one of his famous attributes. Hence, we assume that users will expect him to ask a lot of questions. This could make it feel more natural and therefore less annoying to receive frequent questions during making. For people seeing Toni and Bella as too annoying or childish, Sherlock could provide a more serious, but still playful environment. This agent's story is the following: Sherlock is on a secret mission and his only hope for solving it is the project the maker is going to build. Sherlock wants to know every little detail of the maker's process, to be able to solve the crime and therefore needs the user's help. Using the shape of Benedict

Figure 3.3: Agent Sherlock

Cumberbatch, who plays the role of Sherlock Holmes in a BBC series, may have positive effects due to its alleged attractiveness. As we showed in section 2.3.1, attractiveness generates a more enjoyable user experience. Cumberbatch was voted to be the sexiest movie star in the world in 2013[6].

The shape of Benedict Cumberbatch might provide an attractive agent

Sherlock's exact introduction is: "Hello, my name is Sherlock Holmes. I am a detective and here to solve the mystery of the makerspace. Watson told me that you are inventing something that could be of great help for my case. So I came to watch you building it to be able to solve the case. But in order to be able to solve it, I will need a lot of your help. You will have to tell me every little detail of your process. And please be precise. Otherwise I will ask you a lot of questions to be sure not to miss anything. Are you ready to start working?"

[6] https://www.dailymail.co.uk/tvshowbiz/article-2441280/Benedict-Cumberbatch-Emma-Watson-voted-SEXIEST-movie-stars-world.html

Chapter 4

Study

We set up a study to investigate the usefulness of the documentation agent system. Specifically, we were interested in the annoyance factor of the agent and the time difference between building a project and additionally documenting it, compared to building a project and generating the documentation with the help of the virtual agent system. To investigate if the system can help to bridge the knowledge gap between documentation writer and documentation reader, we were interested in whether the system makes the user more aware of important parts a documentation needs to contain in order for beginners to be able to reconstruct the project. Additionally, we wanted to find out how users perceived the appearance and personality of the agents.

A study should investigate the annoyance factor and time difference of using the system

It should also show whether the system can bridge the knowledge gap of beginners and experts

4.1 Experimental design

The study was split into two rounds of making (documenting the project themselves and documenting with the assistance system) using a between-groups design. The second round was additionally split into three groups, one for each of the agents (Bella, Toni, Sherlock). The participants were distributed randomly among those tasks. Between the two rounds, we inserted a data collection phase to improve our

Between-groups design with two rounds for using the system and not using it and a data collection phase to prepare the second round

own documentation and the kind of questions the agents need to ask in the second round.

4.2 Participants

6 participants for each round and 12 for the data collection phase

12 participants, 7 male, 4 female, 1 NB took part in the study. They were between 16 and 50 years old with an average age of 29.8. Each of them had prior knowledge of working with micro controllers. The participant's nationality was mostly German, additionally we had one Russian, one Canadian and one Spanish participant. Furthermore, we recruited 12 participants without prior knowledge of micro controllers for the data collection phase. The participants were not compensated for their time for this study.

4.3 Task description

Users had to build an Arduino social distancing detector and document their project with or without the help of the assistance agent

We split the study into two rounds. In the first round we required the participants to build a social distancing detector and document their project. The detector should work with an Arduino Uno controlling an ultrasonic sensor to measure the distance between people. The system was supposed to emit an LED as soon as someone gets closer to the ultrasonic sensor than 1.5m. In the second round we split our participants to use one of the documentation agents Toni, Bella or Sherlock. They were instructed to build the same project as the other makers in the first round but did not have to write the documentation on their own. The system kept asking questions during the process and some additional questions when they were finished. The system also asked the user to take a photo of the finished project and to send those via Zoom chat function. After finishing the project, the makers were given the chance to modify the generated documentation if they wanted to. Between the two rounds, we conducted a data collection phase, in which novice users needed to recreate the project with help of the expert's documentation from round one. They were allowed to ask questions in order to be able to rebuild it if

the instructions were not clear enough.

4.4 Apparatus and setup

The study was executed remotely via Zoom to ensure a compliance with COVID-19 regulations and to keep the participants safe. Participants received the components for the project via no-contact delivery to their homes. The components were an Arduino Uno, an ultrasonic sensor, an LED, a resistor, a breadboard, and jumper wires to connect everything properly. For observation purposes, the participants were required to start a Zoom session on their computer as well as on their phone or tablet for an additional angle. The virtual agents were designed using Adobe Photoshop and Adobe Character Animator. Toni is based on the Adobe Puppet Blank[1] and edited to look as mentioned in section 3.2.3. Bella is based on a comic picture of a dog from Pixabay[2] and converted to look more like a Labrador according to the description of section 3.2.2. Sherlock was created from scratch. During the study the agent was shown inside Adobe Character Animator on the observer's screen. The software tracks the observer's head movement to move the puppet according to it. It also lip synchronizes while the observer is talking. The agent was shown to the maker via screen sharing and controlled by the observer in a Wizard Of Oz scenario. The puppet was controlled via face tracking and microphone. The allegedly generated documentation was written in a Google Docs format in order to have a format that all users are able to open and edit no matter which operating system or device they use, as well as for easier sharing. Only one user had difficulties opening the google docs file and therefore received a converted .odt file to edit.

The study was executed remotely via Zoom

The virtual agent was controlled via Adobe Character Animator face tracking (Wizard of Oz)

The resulting documentation was prepared in Google Docs

[1] https://pages.adobe.com/character/en/puppets.html

[2] https://pixabay.com/de/illustrations/hund-cartoon-tier-kinder-orange-5300572/

4.5 Procedure

Users were assigned randomly

They received the Arduino kit and a Zoom invitation

After randomly assigning the users to either study round one or study round two, each user received an Arduino Kit with all required material and an informed consent form to read and fill out. After finding a fitting time slot for the user, they received a Zoom conference invitation and were told to log in to the session with two devices to provide two different angels to the observer. When observer and participant joined the meeting, the observer explained the procedure to the maker and asked for consent to start the recording for internal use.

4.5.1 Study round one

Screen sharing was used to track users actions

Makers were ask to build the project and to write a documentation

Afterwards they had to answer a survey and interview questions

The makers in round one were asked to share their screens to provide better insight on whether they were documenting, coding or doing research. They were told to build a social distancing indicator with the given components and write a documentation in a way that Arduino beginners would be capable of rebuilding the project by reading the documentation. The documentation was supposed to work for people without prior electronics or programming knowledge. During the making and documentation process the observer measured the time of the documentation process and the number of interruptions from making to work on the documentation. After participants completed the project, they could stop sharing their screen and the screen recording was stopped. They were given a google forms survey to answer demographic questions as well as information about their making and documenting experience and their impression on how annoying the documentation process was for them. Afterwards, the screen recording started again with permission of the user and we conducted a semi structured interview to find out more about what users like and dislike about the documentation process, using the following questions 1 and 2.

1. Did you have fun documenting this project?

2. If you could outsource parts of the documentation process to another person, what parts would that be?

Questions 3 and 4 aimed to find out if they would trust someone else or an AI to document the work for them.

3. Would you like to have an assistant that watches you working, asks you questions and writes the whole documentation for you?
4. And what if it wasn't a human, but a computer system?

The last question aimed to find out whether the users of the agent system were more aware of things that need to be in a documentation than the users of round one.

5. Can you enumerate the things that the documentation of the project needs to contain in order for their readers to rebuild it?

When the interview finished, users were thanked for their participation and the Zoom conference ended.

4.5.2 Data collection phase

In the data collection phase beginners tested the expert's documentation

Between the two rounds we used the documentation created by the experts to test it on novice users and identify questions they might have on the project. We took users without prior knowledge on Arduino programming, gave them the documentation and let them recreate it. The users were told to ask as many questions as needed about information missing from or unclear in the documentation. In that case they got extra help by the observer. After they successfully recreated the project we did a retrospective testing by watching the screen recording together with the user and asked questions on their thoughts during the making process to get a better insight on problems they had. Before study round one we already created a documentation on

A documentation was create using guidelines before

What kind of sensor are you using?
Are the colours of the wires important?
At which pin did you put that wire?
Is the colour of the LED important?
Which direction did you put the LED?
How much Ohm does the resistor have?
Could you please write comments to your code, so others and I can understand it better?
Why are you using a delay of x microseconds? Could it also be more or less?
Is the print important or only for testing?
Can you explain the formula for the distance for me?

Table 4.1: Questions the agent asks

our own containing all the information we thought would be necessary to recreate the project. In order to create a useful documentation, we used guidelines from a concurrent evaluation related to the same project on how to build a good maker process documentation [Huff, unpublished to the time of this thesis - May 2021]. With the additional information which questions the novice users asked during the process we were able to optimize our documentation for novice users. Additionally, we were able to gain a better understanding of the kind of questions the agent in round two needs to ask the maker to generate a good documentation. After the retrospective, we thanked the users for their time and effort and ended the Zoom call.

The beginners questions helped to complete the prepared documentation

4.5.3 Study round two

In the second round, users were asked to build the same project, but they did not have to document the work on their own. They were given one of the documentation assistants via Zoom screen sharing. In order to avoid users noticing the Wizard of Oz scenario, the observer had to switch off the camera to operate the agent. Before starting the screen sharing, the observer explains that users can talk to the agent naturally and that it will introduce itself before they start building the project. After starting the screen sharing the agent introduces itself to make the user aware

Makers used a simulation of the agent system for their documentation

of the agent's personality and how to interact with it. Afterwards it asks the users what they are going to build and then requests them to start building. During the making process the agent keeps asking questions about the project. The questions that were asked are summarized in table 4.1. In case the users make clear that they are not aware of how much Ohm the resistor has, the agent offers to help, asks for the colours of the resistor and tells the users how much Ohm it has. After important successes like finishing the connections or finding an error, the agent shortly expresses its joy and congratulates on the big step. When the user is done with the project, the agent asks the user to take a short video of how the project works and to take a picture of it. Finally, the agent asks for the title of the documentation, advises to send the pictures via Zoom chat and says thank you and goodbye. When the pictures arrive in the chat, the observer quickly replaces the picture and title in the google docs documentation that has been prepared before the study and then sends the link via Zoom to the user, who can then decide to make changes in the documentation. After editing, the users are asked to fill out a Google Forms survey on their demographics, their Arduino and documentation experience, their impression of the assistant and their impression of how annoying the documentation process was for them. Similar to study one, the users have to take part in a semi structured interview to find out more about user's thoughts on the system with the first three questions.

The agent offers help on the resistors strength and the direction of the LED

The observer quickly replaces pictures and title in the prepared documentation to fit to users project
The user can make changes on the documentation

Users had to take part in a survey and an interview

1. Would you use the system in the future or not? (why?)
2. What did you like about the system?
3. What did you not like about the system?

To find out about their thought on the virtual agent's appearance and personality the following two questions were asked.

4. What are your thoughts about the character's appearance?

5. What are your thoughts about the character's personality?

To find out what users think of the documentation result and the way they got there questions 6 and 7 were asked.

6. Did the generated documentation meet your expectations or did you miss anything or would you have done something differently?
7. During your work with the agent. What are your thoughts on whether the agent supported you during the making process leading to the finished documentation in the end?

To generate more insight in what users could imagine to be improved in the system we asked question 8.

8. Do you have suggestions to improve the system?

The users also received the same task to enumerate things that the documentation of the project needs to contain to compare it with round one users.

9. Can you enumerate the things that the documentation of the project needs to contain in order for their readers to rebuild it?

After the interview, we thanked the participants for their time and effort and ended the Zoom call.

4.6 Measurements

Time it took to document and make

Number of interruptions

We measured the time it took for the makers to build the project including the documentation. Additionally, we counted the number of interruptions and measured the overall time of all interruptions as documentation time. An

interruption is every part of the making process that is not explicitly making itself, for example if the user stops the work to write down notes, to write the documentation, take pictures or answer the questions of the agent. We differentiate between deep interruptions for interruptions where the user stops working completely to concentrate on the documentation and focus interruptions when users talk or listen to the agent while they are building (given it influences the speed of their building). With the survey, the user's annoyance about the documentation process is retrieved on a 5-point-Likert scale and, in case they had an agent, their impression of the agent. The impression of the agent is measured with the godspeed questionnaire of likeability and perceived intelligence from [Bartneck et al., 2009]. This questionnaire was originally invented to measure human robot interaction, but it has also been used before to measure the difference between a real robot and a virtual robot by [van Maris et al., 2017]. Therefore the questionnaire is used to measure the impression of the virtual agent's perceived intelligence and likeability, which correspond to the two most researched personality traits *competence* and *warmth* as mentioned in chapter 2.3.2. The scales from 1 to 5 chosen for friendliness were:

Annoyance factor

Godspeed questionnaire about the agent

1. 1 = Dislike ; 5 = Like
2. 1 = Unfriendly ; 5 = Friendly
3. 1 = Unkind ; 5 = Kind
4. 1 = Unpleasant ; 5 = Pleasant
5. 1 = Awful ; 5 = Nice

The scales from 1 to 5 chosen for competence were:

1. 1 = Incompetent ; 5 = Competent
2. 1 = Ignorant ; 5 = Knowledgeable
3. 1 = Irresponsible ; 5 = Responsible
4. 1 = Unintelligent ; 5 = Intelligent

Agent	Overall time	Documentation time	Making time
NoAgent	159	75	84
NoAgent	89	64	25
NoAgent	84	46	38
NoAgent	180	120	60
NoAgent	76	39	37
NoAgent	118	89	29
Sherlock	50	18	32
Toni	51	21	30
Toni	36	19	17
Bella	75	11	64
Sherlock	72	16	56
Bella	28	9	19
Average no agent	117.67	72.17	45.5
Average with agent	84.83	15.67	36.33

Table 4.2: The overall time to make and document, time to document/write notes/talk to the agent and the pure making time for each user and agent type

5. 1 = Foolish ; 5 = Sensible

Number of things a documentation needs to contain

In the interview, the users were asked to enumerate things a good documentation needs to contain in order to find out if the agent can make the participants more aware of important components of a documentation. The interview also aimed to perceive a better insight on whether people are positive or negative about the idea of a virtual agent documentation assistant.

4.7 Results

Making and documentation times were smaller with agents

Users in round one needed an average of 117.67 minutes to execute making and documentation while users in round two only needed 84.83 minutes to complete. The average documentation time was also higher for round one with 72.17 minutes against only 15.67 minutes for round two.

Agent	deep interruptions	focus interruptions	overall interruptions
NoAgent	3	0	3
NoAgent	4	0	4
NoAgent	1	0	1
NoAgent	6	0	6
NoAgent	1	0	1
NoAgent	2	0	2
Sherlock	14	0	14
Toni	13	7	20
Toni	11	2	13
Bella	17	0	17
Sherlock	10	3	13
Bella	6	9	15
Average no agent	2.833	0	2.833
Average with agent	11.833	3.5	15.333

Table 4.3: Number of the different types of Interruptions for each user and agent type

Even the pure making time without documentation times is slightly higher for round one with 45.5 average minutes compared to 36.33 minutes for round two. In table 4.2 the individual values per user are displayed. For each column, the longest three times are marked in red and the shortest three times are marked in green.

Number of interruptions was higher with agents

The users in round one often finished their project before starting to document which leads to a number of one interruption. Only a few took notes in between. This group had an average number of 2.83 interruptions. In round two, users got interrupted by the system more often as shown in table 4.3, leading to an average of 15.33 interruptions. From those interruptions 11.83 are deep interruptions and 3.5 are focus interruptions. The makers of round one did only have deep interruptions as focus interruptions only occurred when the makers were talking to the agent in round two.

The annoyance factor was slightly lower with agents

The overall annoyance of the process was 1.92 on a 5-point-Likert-scale. The average annoyance for the agents is a lit-

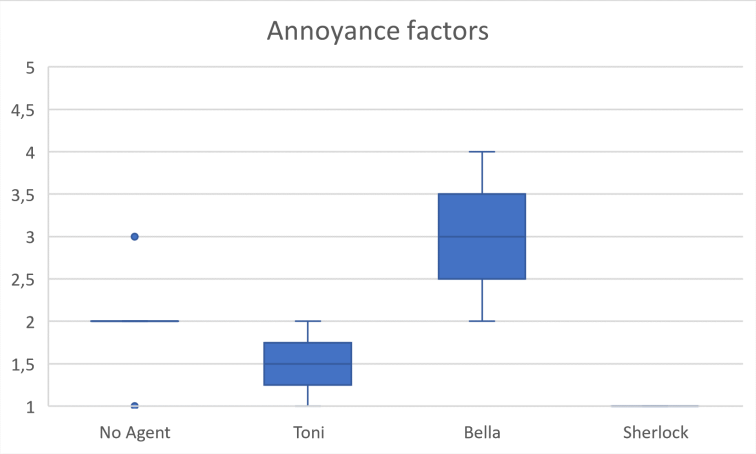

Figure 4.1: Annoyance factor on a 5-point-Likert scale by Type of Agent (rated by six users for No Agent and each two users for Toni, Bella and Sherlock)

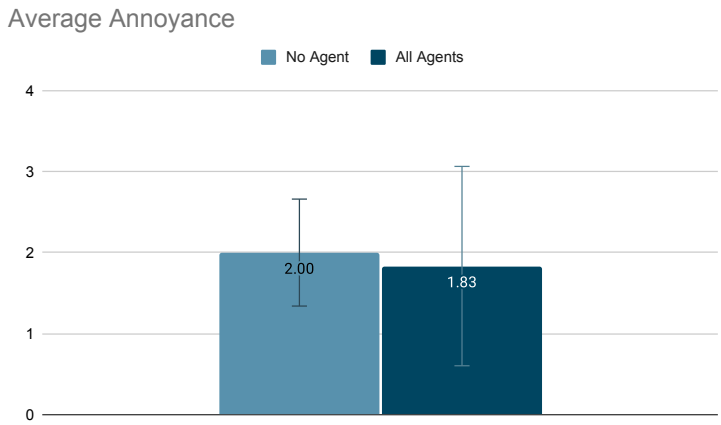

Figure 4.2: Annoyance factor on a 5-point-Likert scale including the 95% confidence interval of 0.66 for people who did not use the system and 1.23 for people who used the agents

tle lower with 1.83 than the general documentation (round one) with an average annoyance of 2. Both rounds had a minimal annoyance value of 1, but the maximal annoyance value of round 1 was 3 while it was 4 for round 2. An overview of all values is shown in the boxplot in Figure 4.1.

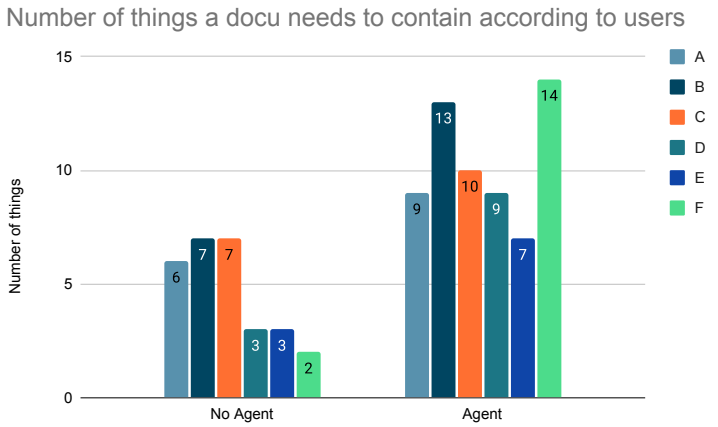

Figure 4.3: Number of things a docu needs to contain enumerated by each user grouped into users with and without agent. The letters of the legend are the identification numbers of the users (NoAgent 1A-1F, WithAgent 2A-2F).

Figure 4.2 show the average values for using the agents or not using the agents including a 95% confidence interval. The CI for not using an agent is 0.66 and the CI for using an agent is 1.23.

Knowledge for documentation content was higher with agents

Users that used the documentation agent were able to enumerate more things that a good documentation needs to contain (in average 10.3) than users that wrote the documentation themselves (average of 4.7). The values can be seen in the barchart shown in Figure 4.3. Figure 4.4 shows the average values compared in a barchart. It includes the 95% confidence interval of the group not using agents being 2.36 and a confidence interval of 2.79 for the other group.

The agent's personality was perceived as friendly, helpful, not annoying, reserved, objective and more

The average Godspeed Questionnaire results with 95% confidence intervals are illustrated in Figure 4.5. The CI values are likeable: 0.43, friendly: 0.57, kind: 0.57, pleasant: 0.54, nice: 0.54, competent: 1.03, knowledgeable: 0.66, responsible: 0.94, intelligent: 0.79, sensible: 0.79. Figures 4.6, 4.7 and 4.8 show the ratings for each agent individually. The participants described the agents in the interview as kind, nice, friendly, empathetic, helpful, attentive, patient, not annoying, neutral, objective, direct, distanced, reserved, not very

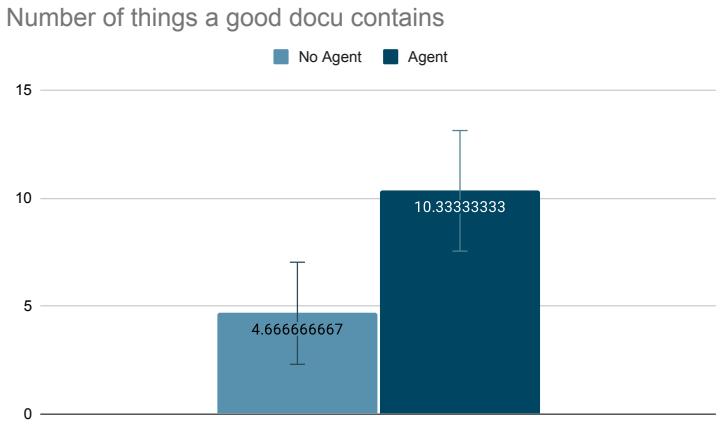

Figure 4.4: Average number of things a docu needs to contain enumerated by each with 95% confidence interval of 2.36 for users that did not use the agent system and 2.79 for the group using the system

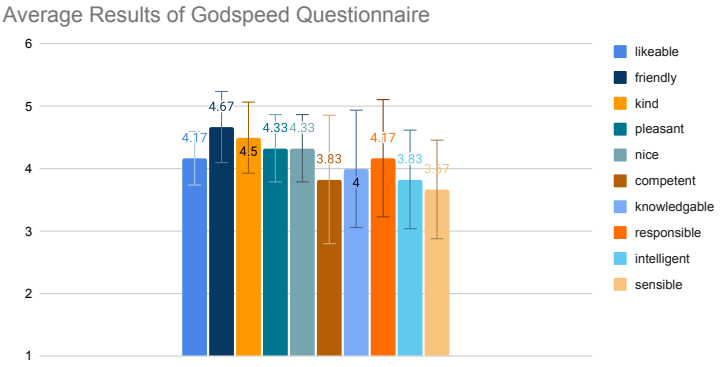

Figure 4.5: Average Godspeed Questionnaire results with confidence intervals

talkative, not too vocal, interested and curious. They also said they felt comfortable talking to them, the voice had not much emotions and they did not always know if the agent was listening.

People did not look at the agent a lot

The appearance of the agents did not matter for most of the participants as they rarely looked at it. Some also said

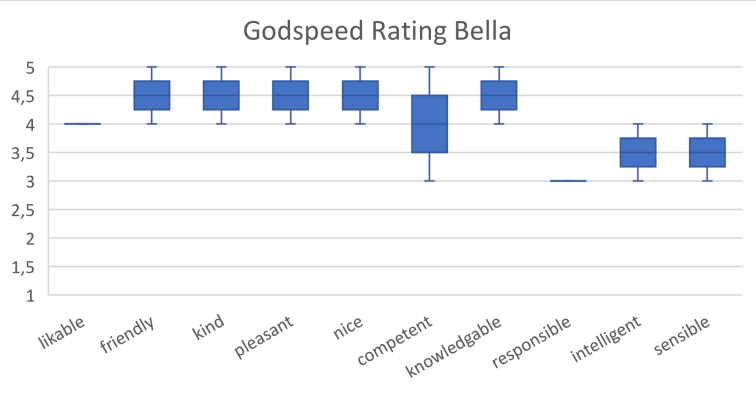

Figure 4.6: Boxplot of the Godspeed Questionnaire results of Bella - 5-point-scale foreach attributed voted by two participants

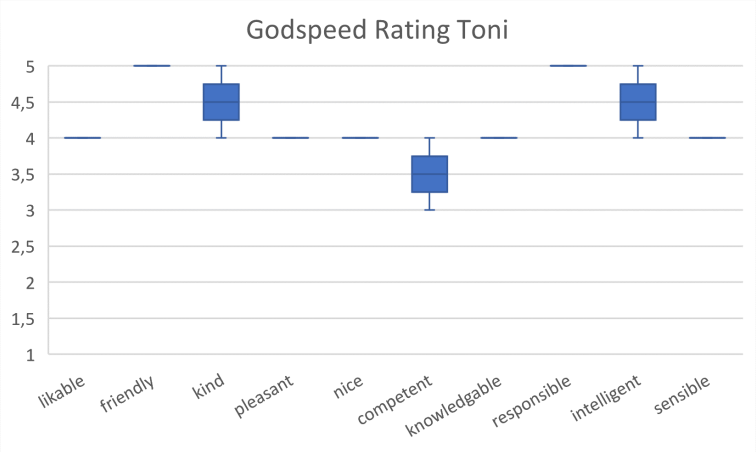

Figure 4.7: Boxplot of the Godspeed Questionnaire results of Toni - 5-point-scale foreach attributed voted by two participants

it did not matter to them whether the agent was a human, animal, an "Arduino with a face" or only a voice. One person stated that Bella was too immature and they preferred a grown up person instead of a dog. Sherlock's appearance was once described as not so appealing. Toni's gender could not be told by one person, while the other person was also unsure, but guessed it could be female because of the voice. Another person did not like the animations and de-

Appearance was said not to matter to the users
Bella was described as too immature, Sherlock as not so appealing and Toni's gender was not clearly recognized

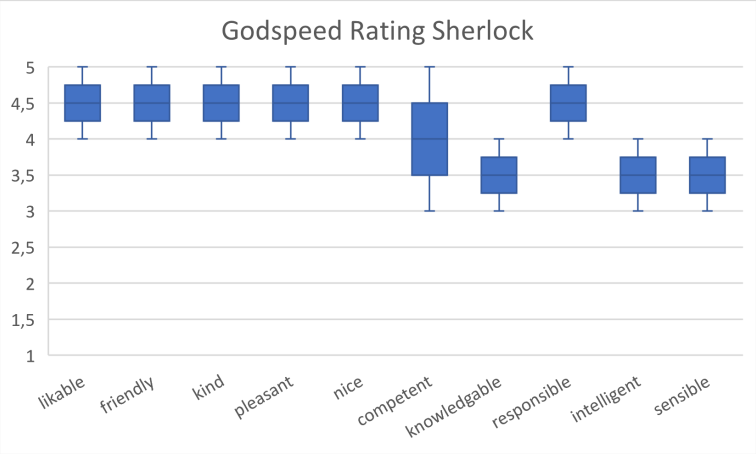

Figure 4.8: Boxplot of the Godspeed Questionnaire results of Sherlock - 5-point-scale foreach attributed voted by two participants

scribed those as strange and did not like that Bella did not blink very often.

Most people would use the system again

Five of the six participants stated that they would use the system in the future. Two of them added that it has to be accurate in a way that they will not have to change too much about the documentation in the end. Only one person did not want to use the system again, because the user already has a working concept on how to document projects and also stated to be distracted by questions. People liked that the system saves them work so they do not have to write a lot.

Users were mostly satisfied with the detailed documentation

The resulting documentation was mostly described as more detailed than expected, including things they did not think of mentioning before. Still, users liked the possibility to edit the documentation in the end, even though most users did not change anything. Only one person changed the order of the chapters in a way that more professional makers could easier skip the theory part in the documentation and another person simplified the formulation of one sentence. Even though they did not edit much in the documentation, in the interview they mentioned that the documentation was missing a section about further steps, the lines

in the diagram were not even enough and the purpose of the project and the pins could have been explained a little more detailed. One user described the documentation as too detailed, but pointed out that this still might be useful for beginners. As the resulting documentation was often clearly different from the project built by the users, one user wished for the system to ask if it could change parts, or at least explain why it does so.

Users liked the help function, but were unsure how to use it

Users also appreciated the help the assistant provided. They liked that it reminded them to write comments, take pictures and videos, but was also able to help them tell which LED leg is anode and which is the cathode and how much Ohm their resistor has. However, it was not easy to know what things to tell the agent to receive the needed help as it was stated by one of the participants. Another person was disappointed that the assistant could not answer all the questions.

Agents questions made people think more about their project

Some users liked that the system forced them to rethink parts of their project and try to understand their projects better. E.g., some people simply copied the formula for the distance calculation and did not think about how it works until the agent asked them to explain it. One user said that saying things out loud makes them "more present in the head". On the other hand, some participants did not like the detailed questions, because it made them doubt themselves when they were not able to answer them right away. Users had to get accustomed talking to the system and sometimes forgot about it. Some parts like the connections were also difficult to explain for them. They stated that they were unsure how to explain things as they did not know how the input is processed. The questions were annoying at points where the users did not know what they are going to do themselves yet. Another thing people complained about was that they had to talk in English when their mother tongue was another language. They usually prefer talking in their mother tongue.

They were not always sure how their input is processed

English was difficult for some German users

Some people said it is different to work with a computer than with a human

Users in round one pointed out differences between using a computer system or a human assistant. They said they would have small talk with humans which would not be the case for computers. Also working together with other

people was said to often be more productive than alone. On the other hand they pointed out that in front of a human they would be more afraid of failing than in front of a computer. People had different opinions on whether they trusted humans or computers more with helping them to document. Some even said it was no difference whether it was a computer or human. In most cases they would still like to check the generated results no matter if it was generated by a human or computer. Users also had different ideas about how to improve the system.

Trust in computers or humans varies between users

Users wished for the agent to ask questions after the connections are done and not before. Especially as connections might be changed several times until they are correct. Additionally, they wished to be asked about their general plan in the beginning, so they can think about the procedure before starting. Another user wanted to be asked by the system to include links in the documentation they come across while using google to find out how to build their project. Someone suggested to generate the documentation during the process and display it to the user while building. This way it could already give the maker a theory explanation of how to use the parts before the maker even starts working. Users also were not happy about the Zoom, phone and double screen setup. Some wanted prepared hardware to work with. Another user even suggested to not use an application at all, but a device. The suggestion was a device similar to the Tonie Box[3], where users could place different figures on a speaker box to have a personification of the voice speaking to them. The Tonie Box is a speaker in the shape of a cube. It was invented as a playing device for children's audio books. Children can place a figure on the box and it starts playing the audio book or music file that belongs to the figure. The movement of the animated agent was not much noticed by the users and therefore a static figure was suggested to be enough.

Users whished for a better timing of questions sometimes

Suggestion to automatically include links they come across during research

Suggestion to show documentation generation during process

User suggested something like a Tonie Box instead of animated agent

The evaluation of the experts' documentation of round one was helpful to make the resulting documentation for round two more understandable and complete. Beginners mostly had problems to rebuild the project when experts forgot to include information like the handling of the Arduino

The beginners asked questions that helped to improve the prepared documentation

[3] https://tonies.de/toniebox/

IDE, or how to connect and disconnect the board to the computer. Technical terms were also not clear for all beginner users. Some users could not find the part that belongs to the word breadboard or LED and they often did not know which part is the ultrasonic sensor, or especially what it does or how it works. The beginners often asked about whether they can use alternative options like another colour for the wire, the direction of the resistor or connecting to another GND pin. They often overlooked instructions or were not aware that they were important, as the direction of the LED or the different colours of the provided resistors. They also often did not realize that they had female-to-male jumper wires additionally to the male-to-male jumper wires that they could use to connect the ultrasonic sensor. When it came to the programming part, the instructions usually told the beginners to copy and paste the provided code to the IDE. With this instruction users often had to ask whether they need to replace the content in the IDE or put it somewhere behind or before that. The experts documentation mostly did not explain the purpose of the project or how to use it. So users were often not aware of what they were building or how to use it in the end. The documentation we provided as result of the system was adapted to tackle all those questions users asked and tried to make certain steps even more clear, so users would not miss them.

Technical terms were often not explained enough

Beginners asked for alternatives that documentation did not provide

Programming instructions were often not clear enough for beginners

Chapter 5

Evaluation

In this chapter we evaluate the results shown in section 4.7. First, we discuss the perception of the agent by the users and compare it with the intended perception of appearance and personality. Then we evaluate the system in terms of usability and the success of bridging the knowledge gap between beginners and experts. Finally we analyze the user's needed time to build the project, the number of interruptions and their annoyance.

5.1 Perception of the agents' appearance

The cartoon style avoided uncanny valley

The virtual agents' cartoon style appearance seems to have avoided the Uncanny Valley Effect (see section 2.3.1), as no user described a feeling of uncanniness towards the agents. One user even pointed out that the cartoon style is well chosen, as it is not too human.

Toni's gender was not recognized

The gender of Toni was not recognized by one of the two users, which leads to the assumption, that it was rather seen as androgynous than as female or male. The other person also was not sure about the gender and only assumed it to be female according to the female voice of the observer. As the voice of the agent was not considered for this thesis, we assume that the approach to make Toni look non-binary

Figure 5.1: Wordcloud for agents personality description - Agency(assertiveness/competence) and Communion(warmth/morality) values used by participants to describe agents sorted into the categories on a colour scale

succeeded.

Users did not look at the agents a lot

The results of the interviews are, for the most part, not giving evidence on whether the appearance of the agents was attractive as most users did not look at them very often. Only one user described Sherlock as not so appealing. The conclusion for the appearance of the agent is, that it doesn't really matter if the agent is moving at all, as participants did not watch them. A general positive effect of the personification can still not be ruled out.

5.2 Perception of the agents' personality

The agent was perceived as warm

The character personality was planned in section 3.2.1 to be only a little assertive, less competent in makerspaces, but more competent in the documentation process. It was aimed to have high warmth as well as high morality. The attributes used to describe the agents by the users can be sorted into the categories of agency and communion as shown in Figure 5.1. The words "friendly", "helpful" and "empathetic" were described as examples of warmth in [Abele et al., 2016]. The words "kind" and "nice" are synonyms of "friendly" and can therefore also be categorized to the warmth facet. "interested" is related to the example

attribute "affectionate". The attributes "attentive" and "patient" were also sorted into this category as it is necessary to be attentive and patient in order to be helpful and empathetic. For the same reason it could have also fitted into the morality category, but as this decision doesn't change the overall result it is not considered of great importance into which category it belongs more likely. As warmth is related to emotions, the term "voice had not much emotion" is clearly of low warmth. "Not annoying" is not of very high warmth, but also not very low. Therefore it is sorted somewhere in the middle of this category. The words "neutral" and "objective" were sorted into the category of high morality, as those correspond to the example attributes "just" and "fair". The expression "felt comfortable talking to" is also sorted into this category as it describes the example attribute "trustworthiness". The category assertiveness contains "reserved", "distanced", "did not always know if he is listening", "not very talkative" and "not so vocal", which are all the counter parts for the example attributes "self-confident", "assertive" and "feeling superior". The attribute "direct" is more in favour of the assertiveness as it correlates to "self-confidence" and "purposeful". The attribute "curious" can be sorted best into the competence field but is not describing high or low competence, but something in the middle. Curiosity is helpful in order to achieve competence, but expressed curiosity usually also means that some competence is missing.

The agent was perceived as moral

The agent was perceived as less assertive

The agents has a rather neutral competence evaluation

It can be seen that the warmth is really high in this Figure 5.1, even though it has one low statement saying "voice had not much emotion". As the voice is not taken into consideration for this thesis, we can neglect that comment and leave it as further research topic. The high warmth can also be inferred from the Godspeed Questionnaire Figure 4.5. The morality is also very high with four positive words. The communion part of the agents' character is therefore met as planned. The assertiveness is very low as planned with just one word indicating high assertiveness against five comments with low assertiveness. The competence is more difficult to determine using only the interview comments. Only curious can be sorted into that category and this doesn't even say whether it has high or low competence. Although we aimed to achieve a low competence in

The agents personality is mostly met as planned

Competence cannot be evaluated as it was not divided into making and documenting competence

making and a high competence in writing documentation, our questionnaire did not differentiate between those two factors. Therefore we cannot know whether users evaluated the competence of the documentation or the making knowledge and have to neglect the evaluation of those values.

5.3 Usability of the system

Users did not have problems to work with the agents

Users were able to work with the documentation agent without major problems. Each user talked to the system in a way that it was able to collect all needed data. The communication still had small drawbacks. For example in the beginning, users were not aware that the agent can also answer questions about the LED and the resistor strength. Only some users managed to ask the agent for help. The other users had to use a search engine or a multimeter. On the other hand one of the users who found the help function was disappointed that the agent could not answer all of the questions the user had. This is one of the drawbacks of natural language as interaction medium as it is difficult to find out about all the features the agents provide. The help function itself was not the aim of the system and also difficult to achieve if the system is supposed to help with most questions. Having the possibility to help with only a few simple things as in this study made the users question what else the agent can help with and disappointed if it cannot help. Therefore the help function should be neglected in further steps. Also one user was not sure how to talk to the agent, as it was unclear how the agent will process the data and did not get much feedback from the agent.

Help function is not considered to be further developed

5.4 Bridging the knowledge gap

Bridging the knowledge gap was successful

Bridging the knowledge gap between expert and beginner makers was clearly a success. Users were able to enumerate more aspects that a documentation needs to contain for be-

ginner users to be able to rebuild it when they used the documentation system than they were able to by documenting the project on their own. It can be seen in Figure 4.4 that the values for using the agent including the confidence intervals were clearly higher than the values for the users not using the system. The results are also supported by the interview responses of the participants. They said that the questions made them more aware of the process steps and they helped to understand the project better for themselves as well. Additionally the system provided a full documentation to the users including all traps that can be useful for beginner users and that experts usually forget might be important. Therefore users would not even have to be aware of what can be problematic for beginner users to write the documentation, but it can help them with creating documentations manually in the future. One of the users suggested the opportunity to record audio notes for the documentation. We do not see this as a useful feature as audio notes usually simplify the explanation for the author but make it more complicated for the reader.

5.5 Time and Interruptions

Users finished faster with the agents

Documenting usually takes more time than making

Most makers like making more than documenting, therefore the tool is useful

Users were interrupted more by the agent than by themselves

As predicted, using the documentation system allowed users to finish their documentation faster. This can save a lot of time and is therefore a useful attribute of the system that we aimed for. It was also apparent that all except for one user who documented themselves needed more time to document than they needed to build the project. Users that had the assistant instead were faster with documenting compared to making (except for one user who needed two minutes more for making than for documenting). Therefore it is obvious that makers usually spend more time on documenting than on making itself, while as pointed out in chapter 1, they usually enjoy making more than documenting. This is a clear indicator for the usefulness of a documentation assistance system for a large target group. The number of interruptions was also clearly higher for the system than without it as predicted.

5.6 Annoyance

User's annoyance of the documentation process was quite low for both rounds with an average of 1.9. The annoyance of the agent round was slightly smaller, but not much. Sherlock was rated the least annoying agent with a value of 1 and Bella the most annoying agent with a value of 3. Toni had a rating of 1.5. Therefore it can be assumed that the prediction that Sherlock could be seen as more natural to ask a lot of questions and therefore less annoying might be true. Bella even got one rating of 4 by a user who did not want to use the system again as the questions were perceived distracting. The user additionally pointed out to already have a good concept to document projects which is an indicator that users who already know how to document and who feel comfortable in their skills are rather not in the target group of such a system. The other user claimed to not like the childishness of a dog agent. The results have to be evaluated carefully as each agent only had two users testing them and they were not allowed to select the character of their choice, which would be recommended for further development of such a system. This is based on the fact explained in section 2.3.1, that users in favour of personification feel more comfortable with a zoomorphic agent than those who do not like personification. Therefore letting people pick their agent could lead to results more in favour of the agent.

Sherlock was the least annoying

Bella was the most annoying and childish

Users with a good concept of documenting are not the target group

Users should be able to pick their favourite agent

The confidence intervals shown in Figure 4.2 show that the difference between both rounds is not high and both values are rather low.

The difference between the annoyance of using the agent and not using it was very low

Our aim was to develop a system that is as little annoying as possible. Since the annoyance for using the agents was slightly lower than the annoyance for writing documentation, this is a promising factor of receiving an agent that is not too annoying in the end. We assume that a direct comparison of the same user using the agent and not using the agent could give a clearer picture on whether the agent is more or less annoying, as different users have different opinions about documenting in general.

Direct comparison of with and without agent is needed for clearer picture of annoyance

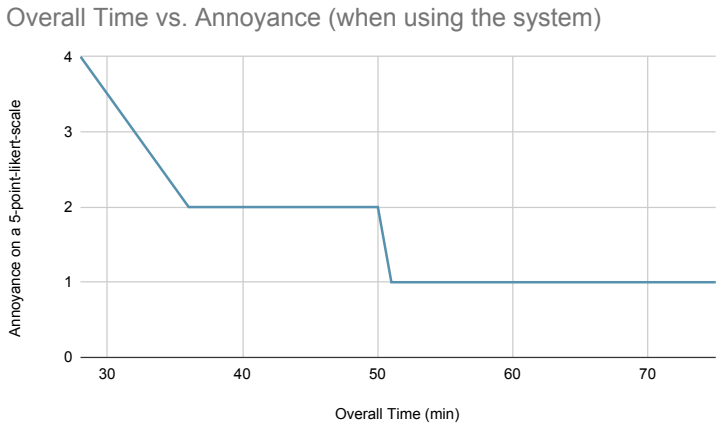

Figure 5.2: The correlation between annoyance and the overall spend time for participants that used the system. Correlation value is: -0.82

We also assume that the number of questions the agent asked was still quite low, such that it did not yet annoy the users a lot. A higher frequency of questions might have a bigger impact on the annoyance. This can also be seen from the correlation value of -0.82 between overall time and annoyance for participants that used the system as shown in Figure 5.2. The more time the users needed to build the project, the less annoyed they were by the questions. We assume that this means a higher frequency of questions is more annoying than a lower frequency of questions, as the number of questions the agent asked was similar for all users.

Frequency of questions might be important annoyance was higher for shorter documentation times when using the agent, therefore the frequency of questions must have been higher

Chapter 6

Summary and future work

This chapter talks about future work, challenges and limitations of the study. It suggests further ideas resulting from the study and summarizes the content of the thesis.

6.1 Limitations

More complicated projects might be more annoying

The results of the study are limited to small and simple projects. It cannot be ruled out that the results differ for more difficult projects. For more complicated projects the agents will probably need to ask more questions in a shorter time which could result in a higher annoyance than it does for small projects like in this thesis. Additionally, more complicated projects require more concentration from the makers. In a deep concentration phase agents' questions might have a higher annoyance value. On the other hand writing the documentation for larger projects yourself will probably also be more annoying as it takes more time and requires you to think of more details. Those details are also more likely to be forgotten in larger projects and therefore require the users to interrupt themselves more often to write down notes. Further research is needed to identify whether larger projects would lead to the same results as it

does for this small project.

Competence cannot be evaluated correctly

The competence of the agent was planned to be not competent in making, but competent in documenting. The study was not able to find out whether this requirement was met as mentioned in section 5.2. Therefore the importance of competence for the virtual agent cannot be evaluated.

Comparing annoyances is difficult

The comparison of the annoyance levels is also quite limited, as people can have a large variety of opinions on whether they like writing documentation or not. Therefore it is difficult to compare the annoyance levels between different users. A direct comparison of one user using the agent system and also writing documentation themselves could give a clearer picture of the annoyance factors.

6.2 Future work

This section is about ideas and suggestions for further development of the system, regarding the appearance of the agent, the talking of the agent, the generation of the documentation and challenges for the development of such a system.

The voice of the agent

In this thesis the voice of the agent was completely ignored as it was considered another facet that will be important in the end, but not as important to highly influence the results of the study in this early step of the research. For further development of such a system the voice of the agent should still be taken into consideration. Attractiveness is described by the Cambridge dictionary as "the quality of being very pleasing in appearance or sound"[1], therefore the voice of the agent could be an influencing factor for the agents' attractiveness. Besides the sound of the voice the speaking rate could also be an influencing factor, that needs to be further researched. Most importantly, the timings of the questions of the agent are crucial. In the study it became apparent that different timings of the questions annoyed

Speaking rate

Timing of questions

[1] https://dictionary.cambridge.org/dictionary/english/attractiveness

the users less or more and this was also stated by them in the interviews. Questions that were asked too early in the process confused and flustered the participants. As some users were not comfortable with talking to the agent in English, we suggest that the system in the future should offer the possibility to choose the spoken language and give possibilities to translate the generated documentation into another language.

Different languages

As the study clearly showed that users did not look at the agent a lot, we would not recommend to follow the path of an animated agent further. we suggest to try a solution suggested by one of the participants. The personification of the agent might still be an influencing factor making the process more enjoyable, but the movements of the agents are not necessary as users do not notice them. Therefore a static hardware figure of a character could be enough to give the user an idea of what the character looks like. The users could get the opportunity to pick one of multiple figures and put them on a speaker device similar to the Tonie Box[2]. This way the character is not in danger of the Uncanny Valley Effect (see section 2.3.1) and there is no need to find the right gestures or the most fitting smile. Additionally, a hardware figure could be more present for the user than an application and might help the users not to forget that it is there and that they need to talk to it.

Change animated agent to hardware agent figure

It is important to let users select their agent of choice, as the perception of the agent is highly dependent on the user themself. This was addressed in chapter 2.3.1. For this study we needed to test all the agents and had to randomly distribute them on the users, so we were not able to let the users decide. To meet different user's expectations, more agents, for example with different ethnicities, have to be added to provide a more diverse set of options. This is based on the fact that users prefer agents that look most like themselves as mentioned in 2.3.1. Therefore, agents with diverse appearance need to be available for all kinds of people. Additionally, this could actively contribute to a broader representation of people of colour in the scientific field, to reduce bias and stereotypes regarding underrepresented minorities.

User should be able to select their agent of choice

Agents from different ethnic groups should be added

[2] https://tonies.de/toniebox/

Direct comparison of agent and no agent is suggested

In order to get clearer results on the annoyance factor of agents, we suggest a direct comparison between using the agents and writing documentation without help. This was not done in this thesis, as it would have influenced the values of the times too much if the users had to build the same project twice, because of the learning effect. We needed them to build the same project, to compare the times it took and to compare the number of interruptions needed. For the future it is suggested to compare the same users using the system and documenting themselves on two different but similarly complicated projects to better evaluate the user's preference in terms of annoyance.

When users decide to do further research apart from the provided links, the system should give the possibility to include the links to the pages they are doing their research at. The resulting documentation of the project should also be evaluated by beginner users to make sure it is complete.

Testing to generate and show documentation while building

For further development of the documentation generation I suggest to look at an approach suggested by one of the participants. As users were unsure about how the things they said were processed, it could be helpful to generate and show the documentation during the building process. This way it cannot only help users understand what the system does with the input but it could also help with the making process. The documentation could show general essential theory information before users thought about it. As soon as they say that they will be working with a certain kind of sensor for example, the documentation could already show theory about how to use the sensor and provide helpful links. However, a constantly changing documentation on the user's screen could be another factor for annoyance and interruption during the making process. Hence, the usefulness of this suggestion needs to be investigated further.

Optional function to let users draw connections instead of explaining them

It could also be useful to let users explain some parts of their work graphically instead of vocally. Especially explaining how users connected the wires was often difficult and took a lot of time. Therefore the system could provide an option to draw the connections graphically instead of explaining it. This is useful for the users who complained about the difficult explanation part for the wires. Addition-

ally there were some users in the first study round who said that drawing the graphs was the fun part of documenting. Therefore giving them the option to still do the schema graphically could positively contribute to a fun experience. Substituting explanations with drawings should be kept optional, since some users did not like the drawing part in documenting.

6.3 Challenges for the system

System needs to know how and when to ask the right questions

To finalize the system from prototype to a final application, several challenges are to be faced. First, the system has to learn how to ask the right questions for the maker's current steps. To be able to know the right questions it has to know what a documentation has to contain and try to fill the gaps in the documentation with the right questions at the right time. Timing is another crucial aspect for the system. It has to find the best timing to ask questions in order to not annoy the users. One point we already found is important for the timing is that the makers get the time to understand themselves what they want to do. Asking users about steps before they are aware of those will raise the annoyance level.

System has to generate a documentation from the user's input and databases

However, the system has to be able to generate documentation from the users voice recordings and a database with basic making knowledge. Receiving knowledge only from the user would lead to a lot more questions, which we assume could lead to a higher annoyance level. The optimal frequency of questions therefore also needs to be further investigated by testing different amounts of questions in a certain time on users and evaluating if there is a threshold of the question frequency before it annoys the users.

6.4 Summary and contributions

The study was designed to evaluate the usefulness of an agent assistant

The aim of the thesis was to explore how a virtual agent for documentation assistance can be designed and whether it

can be a useful tool in the maker communities documentation process. To this end, we designed a study with three different virtual agents that aimed to be attractive, friendly and especially the least annoying as possible. We let users test the system in a Wizard of Oz scenario, in which we controlled the agent's movements and speech and simulated a documentation generation. We compared the annoyance about the agents to the annoyance of users that had to document the project by themselves. Additionally we measured the time it took them to write documentation themselves or talk to the agent to have the documentation generated. In semi-structured interviews we did not only find information about the perception of the agents, but also about whether the system helped the users to achieve a better understanding of useful content in a beginners documentation.

Using the system was compared to writing documentation without such a tool

Between the expert studies we asked people without prior knowledge of Arduino programming to rebuild the project with the experts documentation. This way we were able to find common problems and important information necessary for a good documentation of the project. Furthermore we were able to improve our allegedly by the system generated documentation and find the proper questions agents had to ask.

Data collection phase helped to find common problems of beginners

As a result of the study we can clearly say that using the system reduces workload and especially saves time, which was appreciated by our users. It helps the users by not having to think like a beginner, which often can be difficult as stated by some of the users and also prevents the danger of forgetting to document a step. The annoyance level was quite low in our study for both rounds, but we found a tendency that a higher frequency of questions might lead to a higher annoyance of the user. Furthermore it also made users more aware of their steps. Saying things out loud can make them more aware in the user's mind for example, but also asking to explain certain parts of the project in more detail will make users think more about the reasons for their choices.

The study showed it could reduce the workload and help users to bridge the knowledge gap

The annoyance was not higher when using the agent, but the frequency of questions might influence the factor

Overall, we found that a documentation assistance system can be a useful tool to save time and generate a better un-

The system is useful, but not in the form of an animated agent

derstanding of how to write a good documentation without annoying users a lot, although the usefulness of visualizing the animated virtual agents could not be proven.

Bibliography

Andrea E. Abele, Nicole Hauke, Kim Peters, Eva Louvet, Aleksandra Szymkow, and Yanping Duan. Facets of the fundamental content dimensions: Agency with competence and assertiveness—communion with warmth and morality. *Frontiers in Psychology*, 7: 1810, 2016. ISSN 1664-1078. doi: 10.3389/fpsyg.2016.01810. URL https://www.frontiersin.org/article/10.3389/fpsyg.2016.01810.

Nicoletta Adamo, Hazar N. Dib, and Nicholas J. Villani. Animated agents' facial emotions: Does the agent design make a difference? In Lucio Tommaso De Paolis and Patrick Bourdot, editors, *Augmented Reality, Virtual Reality, and Computer Graphics*, pages 10–25, Cham, 2019. Springer International Publishing. ISBN 978-3-030-25965-5.

Stephanie Chang Lisa Regalla Anna Keune, Kylie Peppler. The maker ed open portfolio project:diy documentation tools for makers. *Indiana University, Maker Education Initiative*, 2015.

S. E. Asch. Forming impressions of personality. 1946. doi: https://doi.org/10.1037/h0055756.

Jeremy Bailenson, Kimberly Swinth, Crystal Hoyt, Susan Persky, Alex Dimov, and Jim Blascovich. The independent and interactive effects of embodied-agent appearance and behavior on self-report, cognitive, and behavioral markers of copresence in immersive virtual environments. *Presence*, 14:379–393, 08 2005. doi: 10.1162/105474605774785235.

Christoph Bartneck, Elizabeth Croft, and Dana Kulic. Mea-

surement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots. *International Journal of Social Robotics*, 1 (1):71–81, 2009. doi: 10.1007/s12369-008-0001-3.

Amy Baylor. Promoting motivation with virtual agents and avatars: Role of visual presence and appearance. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, 364:3559–65, 12 2009. doi: 10.1098/rstb.2009.0148.

Vanessa Bean, Nicole M. Farmer, and Barbara A. Kerr. An exploration of women's engagement in makerspaces. *Gifted and Talented International*, 30(1-2): 61–67, 2015. doi: 10.1080/15332276.2015.1137456. URL `https://app.dimensions.ai/details/publication/pub.1034365388`.

Kirsten Bergmann, Friederike Anne Eyssel, and Stefan Kopp. A second chance to make a first impression? How appearance and nonverbal behavior affect perceived warmth and competence of virtual agents over time. In Marilyn Walker, Michael Neff, Ana Paiva, and Yukiko Nakano, editors, *Proceedings of the 12th International Conference on Intelligent Virtual Agents*, pages 126–138. Springer, 2012. ISBN 978-3-642-33196-1. doi: 10.1007/978-3-642-33197-8_13. URL `https://nbn-resolving.org/urn:nbn:de:0070-pub-25223067`,`https://pub.uni-bielefeld.de/record/2522306`.

Angelo Cafaro, Hannes Vilhjálmsson, Timothy Bickmore, Dirk Heylen, Kamilla Johannsdottir, and Gunnar Valgarsson. First impressions: Users' judgments of virtual agents' personality and interpersonal attitude in first encounters. volume 7502, pages 67–80, 09 2012. doi: 10.1007/978-3-642-33197-8_7.

Arnie Cann and Lawrence Calhoun. Perceived personality association with differences in sense of humor: Stereotypes of hypothetical others with high or low senses of humor. *Humor-international Journal of Humor Research - HUMOR*, 14:117–130, 01 2001. doi: 10.1515/humr.14.2.117.

Justine Cassell. Embodied conversational agents: Representation and intelligence in user interfaces. *AI Magazine*, 22(4):67, Dec. 2001. doi: 10.1609/aimag.v22i4.1593. URL https://ojs.aaai.org/index.php/aimagazine/article/view/1593.

Chloé Clavel, Angelo Cafaro, Sabrina Campano, and Catherine Pelachaud. *Fostering User Engagement in Face-to-Face Human-Agent Interactions: A Survey*, volume 106, pages 93–120. 03 2016. ISBN 978-3-319-31052-7. doi: 10.1007/978-3-319-31053-4_7.

Antonella De Angeli, Paula Lynch, and Graham Johnson. Pleasure versus efficiency in user interfaces: Towards an involvement framework. 04 2002. doi: 10.1201/9780203302279.ch7.

Iwan de Kok and Dirk Heylen. When do we smile? analysis and modeling of the nonverbal context of listener smiles in conversation. In Sidney D'Mello, Arthur Graesser, Björn Schuller, and Jean-Claude Martin, editors, *Affective Computing and Intelligent Interaction*, pages 477–486, Berlin, Heidelberg, 2011. Springer Berlin Heidelberg. ISBN 978-3-642-24600-5.

David DeVault, Ron Artstein, Grace Benn, Teresa Dey, Ed Fast, Alesia Gainer, Kallirroi Georgila, Jonathan Gratch, Arno Hartholt, Margot Lhommet, Gale Lucas, Stacy Marsella, Fabrizio Morbini, Angela Nazarian, Stefan Scherer, Giota Stratou, Apar Suri, David Traum, Rachel Wood, and Louis-Philippe Morency. Simsensei kiosk: A virtual human interviewer for healthcare decision support. volume 2, pages 1061–1068, 01 2014. ISBN 9781450327381.

J M Digman. Personality structure: Emergence of the five-factor model. *Annual Review of Psychology*, 41 (1):417–440, 1990. doi: 10.1146/annurev.ps.41.020190.002221. URL https://doi.org/10.1146/annurev.ps.41.020190.002221.

Claus-Peter H. Ernst and Nils Herm-Stapelberg. Gender stereotyping's influence on the perceived competence of siri and co. In *53rd Hawaii International Conference on System Sciences, HICSS 2020, Maui, Hawaii, USA, January 7-*

10, 2020, pages 1–6. ScholarSpace, 2020. URL http://hdl.handle.net/10125/64286.

Susan Fiske, Amy Cuddy, and Peter Glick. Universal dimensions of social cognition: Warmth and competence. *Trends in cognitive sciences*, 11:77–83, 03 2007. doi: 10.1016/j.tics.2006.11.005.

Yuqian Fu, Chengrong Wang, Yanwei Fu, Yu-Xiong Wang, Cong Bai, Xiangyang Xue, and Yu-Gang Jiang. Embodied one-shot video recognition: Learning from actions of a virtual embodied agent. In *Proceedings of the 27th ACM International Conference on Multimedia*, MM '19, page 411–419, New York, NY, USA, 2019. Association for Computing Machinery. ISBN 9781450368896. doi: 10.1145/3343031.3351015. URL https://doi.org/10.1145/3343031.3351015.

Joseph Grcic. The Halo Effect Fallacy. *E-LOGOS*, 2008(1): 1–6, 2008. URL https://ideas.repec.org/a/prg/jnlelg/v2008y2008i1id245p1-6.html.

Agneta Gulz, Magnus Haake, and Betty Tärning. Visual gender and its motivational and cognitive effects – a user study. *LUCS: Lund University Cognitive Studies*, 137, 2008. ISSN 1101-8453.

Jamin Halberstadt and Gillian Rhodes. The attractiveness of nonface averages: Implications for an evolutionary explanation of the attractiveness of average faces. *Psychological Science*, 11(4):285–289, 2000. doi: 10.1111/1467-9280.00257. URL https://doi.org/10.1111/1467-9280.00257. PMID: 11273386.

Verlin Hinsz, Casey Stoesser, and David Matz. The intermingling of social and evolutionary psychology influences on hair color preferences. *Current Psychology*, 32, 06 2013. doi: 10.1007/s12144-013-9169-2.

Laura Hoffmann, Nicole Krämer, Anh Lam-chi, and Stefan Kopp. Media equation revisited: Do users show polite reactions towards an embodied agent? pages 159–165, 09 2009. doi: 10.1007/978-3-642-04380-2_19.

Matthew B. Hoy. Alexa, siri, cortana, and more: An introduction to voice assistants. *Medical Reference Services Quarterly*, 37(1):81–88, 2018. doi: 10.1080/02763869.

2018.1404391. URL https://doi.org/10.1080/02763869.2018.1404391. PMID: 29327988.

Vivian Huff. Why is the parts list missing? understanding user parameters for hardware documentation selection in the maker community, unpublished to the time of this thesis - May 2021.

W. Johnson and Jeff Rickel. Steve: An animated pedagogical agent for procedural training in virtual environments. *SIGART Bulletin*, 8:16–21, 01 1997.

Bernhard Jung and Stefan Kopp. Flurmax: An interactive virtual agent for entertaining visitors in a hallway. pages 23–26, 09 2003. doi: 10.1007/978-3-540-39396-2_5.

Tomoko Koda and Pattie Maes. Agents with faces: the effect of personification. pages 189 – 194, 12 1996. ISBN 0-7803-3253-9. doi: 10.1109/ROMAN.1996.568812.

Robert Kraut, Paul Resnick, and In Kraut. Encouraging contributions to online communities. 01 2011.

Philipp Kulms, Stefan Kopp, and Nicole Krämer. Let's be serious and have a laugh: Can humor support cooperation with a virtual agent? volume 8637, pages 250–259, 08 2014. doi: 10.1007/978-3-319-09767-1_32.

Anna Keune Stephanie Chang Lisa Regalla Kylie Peppler, Adam Maltese. Survey of makerspaces, part iii. *Indiana University, Maker Education Initiative*, 2015.

James Lester, Charles Callaway, Brian Stone, and Stuart Towns. Mixed initiative problem solving with animated pedagogical agents. 09 1998.

Anthony Little, D. Burt, I Penton-Voak, and David Perrett. Self-perceived attractiveness influences human female preferences for sexual dimorphism and symmetry in male faces. *Proceedings. Biological sciences / The Royal Society*, 268:39–44, 02 2001. doi: 10.1098/rspb.2000.1327.

Gary Mckeown, Ian Sneddon, and William Curran. Gender differences in the perceptions of genuine and simulated laughter and amused facial expressions. *Emotion Review*, 7:30–38, 01 2015. doi: 10.1177/1754073914544475.

Iván Sánchez Milara, G. Georgiev, Jani Ylioja, Onnur Özüduru, and J. Riekki. "document-while-doing": a documentation tool for fab lab environments. *The Design Journal*, 22:2019 – 2030, 2019.

Anu Määttä and Peter Troxler. Developing open distributed tools for fablab project documentation. 01 2011.

Sahil Narang, Andrew Best, Tanmay Randhavane, Ari Shapiro, and Dinesh Manocha. Pedvr: Simulating gaze-based interactions between a real user and virtual crowds. In *Proceedings of the 22nd ACM Conference on Virtual Reality Software and Technology*, VRST '16, page 91–100, New York, NY, USA, 2016. Association for Computing Machinery. ISBN 9781450344913. doi: 10.1145/2993369.2993378. URL https://doi.org/10.1145/2993369.2993378.

Truong-Huy Nguyen, Elin Carstensdottir, Nhi Ngo, Magy El-Nasr, Matt Gray, Derek Isaacowitz, and David desteno. Modeling warmth and competence in virtual characters. 08 2015. doi: 10.1007/978-3-319-21996-7_18.

Magalie Ochs and Catherine Pelachaud. Model of the perception of smiling virtual character. pages 87–94, 06 2012.

Magalie Ochs, Catherine Pelachaud, and Gary Mckeown. A user perception–based approach to create smiling embodied conversational agents. *ACM Trans. Interact. Intell. Syst.*, 7(1), January 2017. ISSN 2160-6455. doi: 10.1145/2925993. URL https://doi.org/10.1145/2925993.

R. Peters, J. Broekens, and M. A. Neerincx. Robots educate in style: The effect of context and non-verbal behaviour on children's perceptions of warmth and competence. In *2017 26th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*, pages 449–455, 2017.

Rosalind Picard. Toward machines with emotional intelligence. pages 29–30, 01 2004. doi: 10.1093/acprof:oso/9780195181890.003.0016.

Tanmay Randhavane, Aniket Bera, Kyra Kapsaskis, Kurt Gray, and Dinesh Manocha. FVA: modeling perceived

friendliness of virtual agents using movement characteristics. *CoRR*, abs/1907.00377, 2019. URL http://arxiv.org/abs/1907.00377.

Byron Reeves and Clifford Nass. *The Media Equation: How People Treat Computers, Television, and New Media like Real People and Places*. Cambridge University Press, USA, 1996. ISBN 157586052X.

Wilson I. M. Monestere C. Bernstein S. Reis, H. T. What is smiling is beautiful and good. *European Journal of Social Psychology, 20(3), 259–267.*, 1990.

Raoul Rickenberg and Byron Reeves. The effects of animated characters on anxiety, task performance, and evaluations of user interfaces. pages 49–56, 01 2000. doi: 10.1145/332040.332406.

V. Schwind, K. Leicht, S. Jäger, K. Wolf, and N. Henze. Is there an uncanny valley of virtual animals? a quantitative and qualitative investigation. *International Journal of Human-Computer Studies*, 111:49 – 61, 2018. ISSN 1071-5819. doi: https://doi.org/10.1016/j.ijhcs.2017.11.003. URL http://www.sciencedirect.com/science/article/pii/S1071581917301593.

Michael Solomon, Richard Ashmore, and Laura Longo. The beauty match-up hypothesis: Congruence between types of beauty and product images in advertising. *Journal of Advertising*, 21:23–34, 06 2013. doi: 10.1080/00913367.1992.10673383.

Jan-Philipp Stein and Peter Ohler. Venturing into the uncanny valley of mind—the influence of mind attribution on the acceptance of human-like characters in a virtual reality setting. *Cognition*, 160:43–50, 03 2017. doi: 10.1016/j.cognition.2016.12.010.

Nicole Sträfling, Ivonne Fleischer, Christin Polzer, Detlev Leutner, and Nicole Krämer. Teaching learning strategies with a pedagogical agent: The effects of a virtual tutor and its appearance on learning and motivation. *Journal of Media Psychology: Theories, Methods, and Applications*, 22:73–83, 01 2010. doi: 10.1027/1864-1105/a000010.

Luke Swartz. *Why People Hate the Paperclip: Labels, Appearance, Behavior, and Social Responses to User Interface Agents*. PhD thesis, 06 2003.

G. Theonas, D. Hobbs, and Dimitrios Rigas. Employing virtual lecturers' facial expressions in virtual educational environments. *IJVR*, 7:31–44, 01 2008.

Jeroen de Boer Theresa Willingham. *Makerspaces in Libraries*. Rowman Littlefield, 2015.

Pascal Thibault, Manon Levesque, Pierre Gosselin, and Ursula Hess. The duchenne marker is not a universal signal of smile authenticity – but it can be learned! *Social Psychology*, 43(4):215–221, 2012. doi: 10.1027/1864-9335/a000122. URL https://doi.org/10.1027/1864-9335/a000122.

Tiffany Tseng and Mitchel Resnick. Product versus process: Representing and appropriating diy projects online. *Proceedings of the Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques, DIS*, 06 2014. doi: 10.1145/2598510.2598540.

Tiffany Tseng and Mitchel Resnick. Spin: Examining the role of engagement, integration, and modularity in supporting youth creating documentation. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems*, DIS '16, page 996–1007, New York, NY, USA, 2016. Association for Computing Machinery. ISBN 9781450340311. doi: 10.1145/2901790.2901868. URL https://doi.org/10.1145/2901790.2901868.

Patricia Valdez and Albert Mehrabian. Effects of color on emotions. 1994. ISSN 0096-3445. doi: 10.1037/0096-3445.123.4.394.

Anouk van Maris, Hagen Lehmann, Lorenzo Natale, and Beata Grzyb. The influence of a robot's embodiment on trust: A longitudinal study. In *Proceedings of the Companion of the 2017 ACM/IEEE International Conference on Human-Robot Interaction*, HRI '17, page 313–314, New York, NY, USA, 2017. Association for Computing Machinery. ISBN 9781450348850. doi: 10.1145/3029798.3038435. URL https://doi.org/10.1145/3029798.3038435.

Nikola Vučinić, Shane Tubbs, Mirela Erić, Vujić Zorica, Dušica Marić, and Boris Vuković. What do we find attractive about the face?: Survey study with application to aesthetic surgery. *Clinical Anatomy*, 33, 08 2019. doi: 10.1002/ca.23455.

J. Walton and E. Adamson. *Labrador Retrievers For Dummies*. –For dummies. Wiley, 2011. ISBN 9781118053676. URL `https://books.google.de/books?id=ylvgMs4qct8C`.

Karen Wilson. Evaluating images of virtual agents. In *CHI '02 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '02, page 856–857, New York, NY, USA, 2002. Association for Computing Machinery. ISBN 1581134541. doi: 10.1145/506443.506633. URL `https://doi.org/10.1145/506443.506633`.

Jun Xiao, John Stasko, and Richard Catrambone. An empirical study of the effect of agent competence on user performance and perception. In *Proceedings of the Third International Joint Conference on Autonomous Agents and Multiagent Systems - Volume 1*, AAMAS '04, page 178–185, USA, 2004. IEEE Computer Society. ISBN 1581138644.

Typeset May 27, 2021