Modelling Social Embodiment in Social Robotic Companions: using Tamagotchi & NAO

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Abstract—Social interactions with robots and agents have become increasingly popular as a way for humans to interact. To be able to provide these social interactions, the embodiment in particular social embodiment for the social agents are considered to be an important factor. In this paper, we introduce an experiment to measure the impor- tance of modelling of social embodiment in social agents. For which we decided to use Tamagotchi architecture in two different configurations as a virtual agent (Graphical user interface) and a physical robot (NAO robot). We then surveyed on interactions with these two different embodiment configurations using a questionnaire and a short interview. Which we then discussed in our results section, showing how modelling of social embodiment in social agents plays an important role in social interactions between humans and robots.

Keywords: Social interactions, NAO robot, social embodiment.

I. INTRODUCTION

Over the last decade, there has been a significant development in the Artificial Intelligence research community regarding the concept of embodiment. Even though the term "embodiment" refers strictly to phys- ical existence, researchers have found that people when interacting with virtual agents considered embodiment as the fundamental feature for their evaluation. This leads us to a research discipline called "Social Embodiment". In this paper, we would like to test and compare the hypothesis - "how human perceive social embodiment in virtual and physical agents". To evaluate this hypoth- esis, we used Tamagotchi architecture in two different embodiment configurations. Section I-A briefly outlines background knowledge on modelling of embodiment, social embodiment and Tamagotchi.Section II provides information on materials and methods used for the exper- iment. Section III provides information on the evaluation setup and experiment procedure. Section V talks about the results obtained from the evaluation experiment. The final Section VI and Section VII seeks discussions and overall conclusion related to the evaluation experiment.

A. Background Knowledge

In this section, we aim to provide the background knowledge required to understand our experiment.

Which includes, understanding of what modelling of an embodiment is, understanding social embodiment and introduction to Tamagotchi.

1) Modelling Embodiment: Nowadays embodiment is considered as one of the major condition for any form of intelligence by most of the researchers in social cog- nition. For example,[3] argued that intelligence cannot merely exist in the form of an abstract algorithm but requires a physical instantiation, a body. But there is always a little argument on what kind of body an arti- ficially intelligent agent should be equipped with. This question then leads to mid-1980s research on different notions of embodiment bodies. As per [6],the author has a distinguished body/embodiment as

- Structural coupling
- Historical embodiment
- Physical embodiment
- Organismoid embodiment
- Organismic embodiment
- social embodiment

This paper is closely related to the social embodiment. Therefore, in the below sub-section, the notion of the social embodiment explained elaborately with respective to our experiment.

2) Social Embodiment: From the above section, we can understand that social embodiment is not a separate discipline. Instead, it is a sub-discipline of embodiment research. This discipline aims to understand how humans process social information. [7] defines the idea behind social embodiment, social inference processes involved in thoughts about the meanings of entities and events are influenced by sensory, motor and perceptual cues in the interaction environment. [8] the author states that the social embodiment has been examined in depth, how concrete cues like warmth, smells, weight, brightness, roughness, elevation, body posture, or motor movements influence user's perception. The author also mentioned that this line of research has repeatedly received criticism due to the lack of demonstration studies. With this as goal motivation in this experiment, we concentrated on building a social agent-based demonstration experiment where the users interact with the social agent which have a different physical embodiment but with a similar social embodiment features. To best of our knowledge, this work is the first experiment of using a social agent to understand the importance of social embodiment in social robots or agents.

3) Tamagotchi: The Tamagotchi [9] is a handheld digital pet created in Japan by Akihiro Yokoi. It is an egg-shaped creature displayed in the small LCD screen. This creature grows and develops over time based on the user caring factor.

Therefore, the goal of the user is to take care of this digital creature like a real-life pet.

Tamagotchi has a Hunger meter, Happy meter, and Discipline meter to determine healthiness and discipline factor of the pet. There is also age and weight function to check the age and weight of the pet. If the pet gets sick, a skull icon appears next to the pet, with an unhappy expression. The pet can become sick for several reasons such as overfeeding or failing to clean up. The pet can die if sickness is left unchecked. The pet can be cured by pressing the "Medicine" option.

The pets also have different life cycle stages like Baby, Child, Teen, and Adult. Usually, the pet's age will increase once it has awakened from its sleep time. With the many different versions of the toy. Tamagotchi had many version from Initial release at 1997 to 2012.

II. MATERIALS AND METHODS

In this section, we will be discussing the major components of our experiment, which are NAO, GUI and User. Every section has a brief introduction and explanation of the methods utilized. In users subsection, we will discuss in detail about participants, questionnaire design and score evaluation.

A. System

1) NAO: NAO [10] is a 58cm tall humanoid robot developed by SoftBank Robotics. NAO is known as the world's leading and widely used humanoid robot for education, health care and research. Its design is intended to make interaction with the user as natural and intuitive as possible. The robot can walk, talk, listen and even recognize faces using its in-build software. In general, the NAO robot has autonomous abilities and makes some autonomous motion based on surroundings. This motions can be restricted and Collision avoidance of the robot can also be disabled which are active by default.

In this experiment, we made the NAO robot to sit and perform the task. So we used API to control and restrict the autonomous motions. Additionally, Joint stiffness is set based on the Tamagotchi architecture. To ensure that the robot autonomously doesn't make any movement.

2) Graphical User Interface: The graphical user interface for Tamagotchi GUI is written in python using the PyQt, which is a python based library for the graphical user interface. It uses both mouse and keyboard events on the user system as input. It also uses speakers to play sound events on the user system.

- Tamagotchi GUI Scripting Tools:
- – Python SDK version: 3.5.2
- – PyQt version: PyQt5
- – Language: English

B. Optimization –Naive Users

In the following, we describe the conducted HRI study with non-expert users, who are naive to this particular study and have little to no Experience with robots. We informed consent was obtained from all participants prior to the experiment.

1) Participants: Participants were recruited through flyers/adds around the campus of Bielefeld University. Six persons took part in the experiment. Participants were age- and gender- balanced (2f, 4 m, age: M = 25.83 with a range from 19 to 35 years).

2) Questionnaire Design: Questionnaire and the interview answers relating to the embodiment were col- lected from the participants. This will give us a general idea about their (self-reported) behaviour before we ana- lyze the actual scores. The responses of the participants, which were reported in interviews and questionnaires can be categorized into five approaches.

- System Usability Scale: The System Usability Scale (SUS) [4] provides a quick and dirty, reliable tool for measuring usability". It consists of 10 sets of questions in the questionnaire with five response options for participants from Strongly agree to Strongly disagree. Created by John Brooke in 1986 [11], it allows us to evaluate social usability of the tamagotchi architecture in two different configurations.

- Anthropomorphism: Anthropomorphism [12] refers to the attribution of a human form, human charac- teristics, or human behaviour to nonhuman things such as robots, computers, and animals. Using God- speed Questionnaire Series [12] appears to be more

suitable. The question was: Fake / Natural, Ma- chinelike / Humanlike, Unconscious / Conscious, Artificial / Lifelike, and Moving rigidly / Moving elegantly.

- Animacy: The goal of many robotic researchers is to make their robots lifelike. For the question- naires in this study, their questions [12] have been transformed into: Dead / Alive, Stagnant / Lively, Mechanical / Organic, Artificial / Lifelike, Inert /Interactive, Apathetic / Responsive.

- Likeability: It has been reported that the way in which people form positive impressions of others is to some degree dependent on the visual and vocal behaviour of the targets (e.g., likeability) [13] of a person often lead to more positive evaluations of that person. liking question with 5-point differen- tial scales[12]: nice / awful, friendly / unfriendly, kind / unkind, and pleasant / unpleasant, because these judgments tend to demonstrate considerable variance in common with liking judgments.

- Perceived Intelligence: Interactive robots face a tremendous challenge in acting intelligently. Com- puters require this formalization to generate intel- ligent and human-like behavior.Warner and Sugar- man (1996) [12] developed an intellectual evalua- tion scale that consists of five seven-point semantic differential items: Incompetent / Competent, Igno- rant / Knowledgeable, Irresponsible / Responsible, Unintelligent / Intelligent, Foolish / Sensible.

- Perceived Safety: Perceived safety [12] describes the users perception of the level of danger when interacting with a robot, and the users level of comfort during the interaction. Achieving a positive perception of safety is a key requirement if robots are to be accepted as partners and co-workers in human environments.

This and later work (Kulic & Croft, 2006) [12] by the same authors showed a strong statistical correlation between the effective state reported by the subjects and their physiological responses.

The scales they produced can be transformed to the following semantic differential scales: Anxious / Relaxed, Agitated / Calm, Quiescent / Surprised. [12] This questionnaire focuses on the effective state of the user.

III. EVALUATION SETUP

In this section, we will be providing detailed infor- mation about designing of Tamagotchi architecture and embedding the decision states and evaluation conditions for the graphical user interface and NAO.

A. Tamagotchi GUI

The Tamagotchi graphical user interface is a simple GUI built upon the architecture of Tamagotchi. As the GUI is a replica of original Tamagotchi, all the features included are extracted and modified based on the need for the experimental setup. The Tamagotchi GUI has
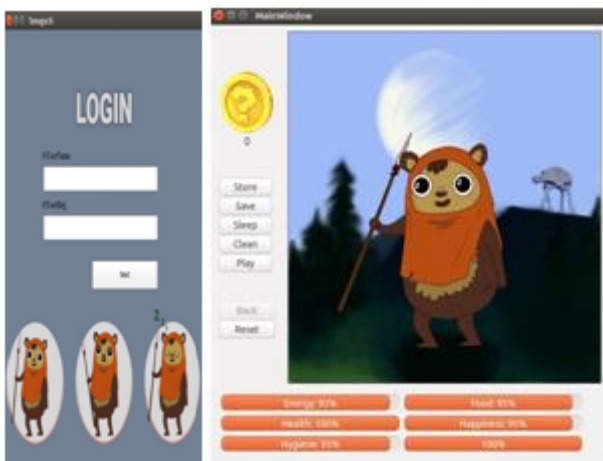

Fig. 1: Tamagotchi Graphical User Interface divided into

two instances 1. the registration page and the main window. The registration page is used for registration of the participant name and registration number, Both the fields are optional. After the Submit button is pressed, the main window is activated with the Tamagotchi. Below we would like to provide you with an elaborate explanation for each feature in comparison the figure 1.

- Gold Coin: This feature provides information re- garding the money which can be used for taking care of Tamagotchi. On start, it is set to zero and will be incremented when the users play a game with Tamagotchi. Upon gaining the coins, users can use them to shop different items at the Tamagotchi store which in return effects different emotions of Tamagotchi.

- Store: This feature provides the users to access the Tamagotchi store from which one can buy useful products needed for taking care of their Tamagotchi. This material includes food, medicine and hygiene products. All these products require gold coins to purchase. With each product has its own identity they play a role in Tamagotchi meter behaviors.

- Save: This feature provides the users to save his/her Tamagotchi's last instance. By which the users can have their Tamagotchi alive, even after they quit the application.

- Sleep: This feature helps the users to toggle and control the Tamagotchi sleep cycle. This feature affects the Tamagotchi energy meter with a positive reward but affects the Tamagotchi food, health, hap- piness and hygiene meters with a negative reward.

- Clean: This feature helps the users to clean the Tamagotchi surroundings when it turns dirty. This feature affects the Tamagotchi's health, happiness and hygiene meters with positive rewards if sur- roundings are clean else with a negative reward.

- Play & Back: These features provide users to ac- cess and toggle back the Tamagotchi game. The Tamagotchi game is a traditional snake game where the goal of the user is to control the snake which increases its length upon eating each dot. In our case for eating each dot, the user is rewarded with one gold coin. If the snake collides its own body the game ends. While playing, happiness and health meters are affected by positive rewards. Whereas energy, food and hygiene are affected by negative rewards.

- Reset: This feature provides the user to reset the whole Tamagotchi GUI to start which includes setting all the meter values to a hundred percent and some of gold coins to zero.

- Meters: There are four states in Tamagotchi GUI 1. normal, 2. playing, 3. sleeping and 4. unhealthy. Based on the states the meter values are updated as shown below.

Along with these features, different sounds were added to make the Tamagotchi GUI more intractable for the users.

B. Tamagotchi Architecture in NAO

The Tamagotchi architecture for the NAO robot is wire-framed based on the original Tamagotchi features. The wire-framed features are then optimized based on the NAO baseline architecture. The architecture is then developed as a state machine with three states embedded with the wire-framed features which can be seen in figure 2.

The designed Tamagotchi architecture for NAO works on user speech input. Therefore, the user will decide which state the robot should be, not only this, but it also opens room for live user NAO interaction which satisfies the social companion role needed for the experiment.

The user can signal any of these three states 1. playing, 2. talking and 3. no response when the NAO is in the idle state. Upon selection, the architecture locks the selected state and perform the functionality related to that state.

```
Algorithm 1: GUI Meter conditions
Result: Determine the mood of GUI agent
initialization;
(All the meters are set to 100%)
while While not reset do
    if state == "normal" then
        Energy meter -4 ;
        Food meter -6 ;
        Health meter -3 ;
        Happiness meter -6 ;
        Hygiene meter -4 ;
        if Hygiene meter ≤ "30" then
            state = "unhealthy" ;
        end
    end
    if state == "playing" then
        Energy meter -8 ;
        Food meter -6 ;
        Health meter -4 ;
        Happiness meter +8 ;
        Hygiene meter -4 ;
        if Hygiene meter ≤ "30" then
            state = "unhealthy" ;
        end
    end
    if state == "sleeping" then
        Energy meter +8 ;
        Food meter -6 ;
        Health meter -3 ;
        Happiness meter -4 ;
        Hygiene meter -4 ;
        if Hygiene meter ≤ "30" then
            state = "unhealthy" ;
        end
    end
    if state == "unhealthy" then
        Energy meter -4 ;
        Food meter -4 ;
        Heath meter -8 ;
        Happiness meter -8 ;
        Hygiene meter -6 ;
        if Heath meter ≤ "10" then
            return "Dead" ;
        end
    end
end
```


Fig. 2: Tamagotchi Architecture in NAO

Below we would elaborately explain each state, with its functionality.

- Idle state: This is the state which controls the whole architecture of Tamagotchi in NAO. The base functionality of this state is to take the user speech input. Once the state is selected, the architecture translates from idle to selected state. After completing the functionality loaded in the selected state, the architecture is translated back to the idle state. This cycle of translation continuous until the user stops the robot. In other words, this state can be referred in short as a state manager in Tamagotchi architecture in NAO.

- Talking state: In this state, the NAO performs the functionality of asking the user a one simple daily life question from its question bank and then waits for his/her speech response. Based on the signal the NAO responds with a small motivational speech and divert the user to play a game with it, translating its state from talking to playing. If the user does not respond to question, then the NAO goes into the feeling state and executes the emotion with respective the emotion meters values.

- Playing state: In this state, the NAO performs the functionality of playing a designed game with the user. The designed game is to touch the NAO parts according to the sequence generated by the NAO. This game has three levels. As the level increases the difficulty of sequence increases, once the user completes all the levels successfully the NAO will translate back to an idle state. If the user does not respond in the level one or fais measuredil to touch the correct part of the body, NAO translates to the feeling state and executes the emotion with respective the emotion meters values. Whereas if the user fails in other levels, NAO translates back to the idle state with a small motivational speech.

- Feeling state: In this state, the NAO performs the functionality of executing the feelings which are designed based on the original Tamagotchi feelings like unhealthy, unhappy, hungry and stable. This state is called whenever there is no speech signal response from the user when NAO is in the idle state. The executed feeling is a mixture of speech and body movement of the NAO. The feelings are executed with concerning emotion meters values. After the change, the NAO is translated back to the idle state.

Note: The word "emotion meters values" referred above is explained in the section III-C.

C. Android Application for NAO

The NAO robot can be used to express the feelings using different features, which explained in the above section III-B. But to understand the exact percentage of emotions we need a user interface. NAO robot is not equipped with its tablet-like pepper robot. So we developed an Android application which gets the data as in figure 3. So the parameters like happiness, health, food parameters calculated by Tamagotchi architecture are sent to Cloud Database (Firebase). These parameters are retrieved from the Firebase database to display in the android application. This application is designed to make a bi-directional communication. The application also has an option to reset the state completely.
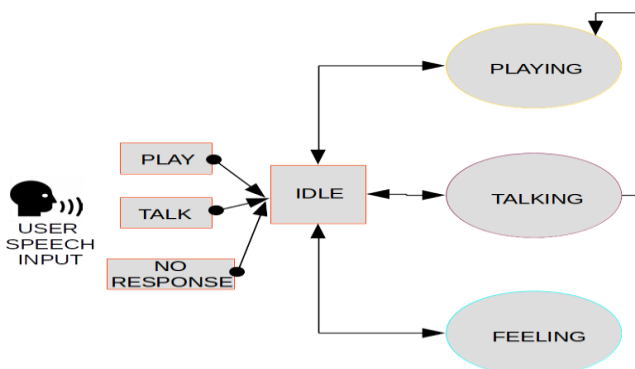
Fig. 3: Data Flow

The Android application has two instances figure 4, the first instance has the registration page where the participant can enter their name and registration number, Both fields are optional. The second instance has 4 me- ters for Energy, Food, Happy, Health which are labeled. These percentage values calculated based on the various conditions mentioned below.

IV. EXPERIMENTAL SETUP

Before the start of the experiment participants were informed about the data protection document, where evaluation conditions, which are needed to be main- tained in the course of the experiment. The list of evaluation conditions are mentioned in the section III-A. Once the user is made to be clear with all the evaluation conditions, a live demo is demonstrated for the user.

After which the user is provided with the system containing the Tamagotchi GUI and interaction time of 25 minutes. Once the interaction time is com- pleted, The user is then provided with a question- naire to be answered. Once the user completes, the experiment room is cleaned and made ready for the next user.
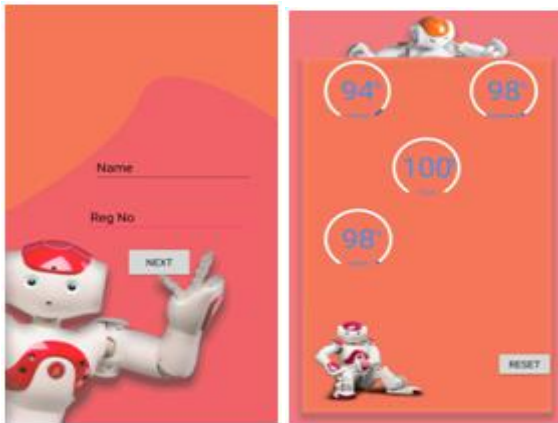

Fig. 4: Anroid Application UI

they were asked sign if they agree to all the mentioned clauses. To evaluate the potential effects of the social embodiment in social robots, we experimented with two different configurations:

- Tamagotchi architecture in GUI (TGUI)
- Tamagotchi architecture in NAO (TNAO)

For the fair study, we decided to make the user select any of one configuration so that the user is not influenced by the other configuration.

- In TGUI case: On start, the user is provided with

Fig. 5: Tamagotchi GUI

- In the case of TNAO: On start, the user is provided with evaluation conditions and android application. The evaluation conditions are explained in detail in the section III-C. Once the user is made to be clear with the evaluation conditions, then a short demo is also demonstrated for the user.

Upon which the user is provided with the NAO along with the android device containing the ap- plication and interaction time of 25 minutes. Once the interaction time is completed, The user is then provided with a questionnaire to answer. Once the user completes, the experiment room is cleaned and made ready for the next user.

V. RESULTS

A. The System Usability Scale (SUS)

System Usability Scale (SUS) is a simple, 10 question- naire that has scale ranging from "Strongly Disagree" to "Strongly Agree" that provides a glance look at the ease of use of a robot or Virtual agent (Tamagotchi in this case). SUS was created by John Brooke in 1986 [4].

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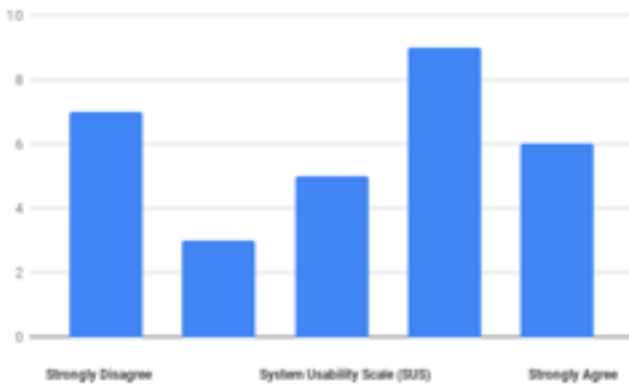
Fig. 6: Tamagotchi NAO

Fig. 7: SUS for Tamagotchi GUI

After using our system, the user filled out a survey for the robot and virtual agent. To make the plot readable, we decided to formulate the scale by taking up the responses of all the users in that condition. Adding individual options of all the responses, then dividing it by the number of users in that condition. It is very evident from the graph 7, 8 that the user Strongly agreed 6 times and
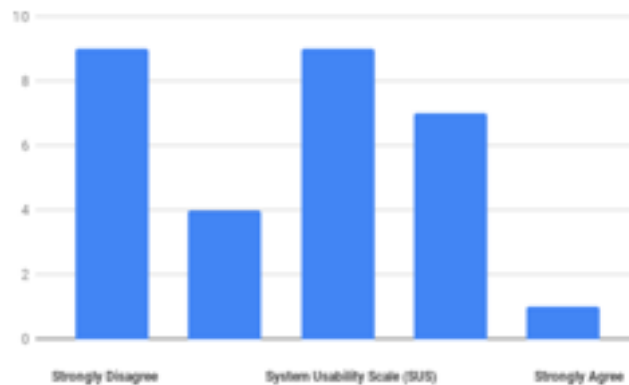

Fig. 8: SUS for NAO Robot

strongly disagreed 7 times to use GUI. In contrast, for Robot (NAO) the user strongly disagreed 9 times and strongly agreed only once.
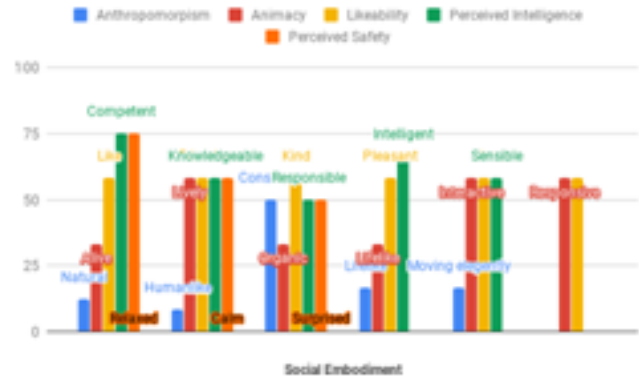
B.   Social Embodiment

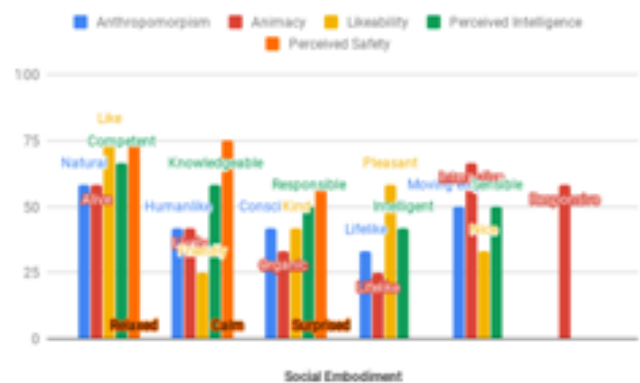**Fig. 9: Social Embodiment analysis for GUI**

Fig. 10: Social Embodiment analysis for NAO Social

Embodiment [12] it is measured based on various factors, Like Anthropomorphism, Animacy, Likeability, Perceived intelligence, Perceived Safety, Which are available in the figure 9, 10. The participants scores for each factors are in 5 point scale multiplied by 20   to convert the original scores of 1-5 to 20-100. Though the scores are converted to 100, these scores are not percentages and should be considered only in terms of their ranking.

From the figure 9, 10, we observed participants pre- ferred NAO robot more than the virtual agent(GUI) in most factors. Where as, participants preferred the virtual agent more when it comes to Likeability and Perceived Intelligence. On average over all the factors, users pre- ferred Tamagotchi NAO with 52.32% in contrast to Tamagotchi GUI with 49.53%.

VI.   DISCUSSION

The primary intention of this research was to test whether users are considering social embodiment as a fundamental feature in their evaluation. The secondary objective was to investigate whether the system usability influenced social embodiment.

To test the above objectives, we modeled Tamagotchi architecture in two different configurations (physical   and virtual).

For physical configuration, we used the NAO humanoid robot and graphical interface for virtual configuration. The user was made to evaluate one of the configurations and feedback as questionnaire was used to determine the results.

Our results support that the user prefers physical configuration more compared to virtual, which provides ground truth for our hypothesis. Our result also signifies that social embodiment is not only deciding factor for the user. Some of the other factors like system usability also play a major role. One possible explanation can be derived from the comments of the participants. In post- experiment interview participants in the TGUI condition reported that agent is very interactive and engaging but they were annoyed of looking into a distracting screen.

At last, a significant difference in time spent by the user was measured between the conditions, Which has no difference in the implementation. Users tend to spend more time with the robot compared to GUI. These results show that it is possible to extend the time of social interaction in GUI by designing agent which are more relatable to human. Our results are in line with the findings from [5]. Their study investigates on the question of how much people would empathize when something bad happens to a physical robot in comparison to simulated variants. They found that people may empathize more with a real robot, and further, found initial indications that people may even fail to empathize at all with simulations. Finally, we outlined important future directions that may be experimented as a result of our findings.

Social Embodiment is an important element of many applications of social robotics, including companion, phycological therapy, and teaching robots. In this paper we have considered two conditions, one is a physical robot and another one is a virtual robot. As future work, it will be really interesting to try if we have one more condition that is having real robot over skype or any virtual environment. Controlling that real robot via voice control through online. Such a condition helps to investigate more into Embodiment and Empathy in HRI scenario. We also suggest from our survey feedback that simulated robot is not a perfect replacement for the real robot, It is always really hard for the designer to design something which is real and humanlike actions.

With these limitations will people empathize with a cantankerous robot in the same way? Given our results and discussion on the importance of robotic embodiment, we believe that such a robot would induce empathy, but this can be further investigated.

VII. CONCLUSIONS

In this paper, we presented a experiment which eval- uates the importance of social embodiment in social agents for social interaction. Subsequently, we also dis- cussed how Tamagotchi architecture was used as a virtual agent[III-A] and as a physical agent[III-B] to set up the experiment. Followed by user interaction and evaluation results based on the conditions[III-A] presented in this paper. We learned that in terms of system usability Tamagotchi GUI is preferred more than Tamagotchi NAO whereas in terms of the social embodiment users preferred Tamagotchi NAO in contrast to Tamagotchi GUI.

In our experiment, we have demonstrated the effec- tiveness and need for social embodiment while designing agents for social interaction. We have also understood that system usability is a major factor in modelling social embodiment. Limitations of our work include the fact that the user group for this survey was limited and the age range of selected user was also not wide.

As to future work, we plan to explore more scenarios like interacting with a physical robot virtually [5]. We would also like to test other scenarios such as a hospi- tal assistant, gym companion to further understand the performance. Furthermore, as short comment use a large user group, involving different age groups and ethnicity. Finally, we would like to build a personalized social em- bodiment system, where the system can be considered as generic architecture for other social embodiment based applications.

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