Social Transmission of Information through Virtual Robotic Agents

Owais Hamid[1][a], Shruti Chandra[2], Kerstin Dautenhahn[2,1] and Chrystopher Nehaniv[1,2]
[1]Systems Design Engineering, University of Waterloo, Waterloo, ON, Canada
[2]Electrical and Computer Engineering, University of Waterloo, Waterloo, ON, Canada

Keywords: Social Learning, Game Environment, Observational Conditioning, Stimulus Enhancement, Response Facilitation.

Abstract: Social learning includes simple or complex social mechanisms that allow us to understand cooperation and communication in animals, giving them better chances to survive for longer and thrive as a society. Specifically, certain types of social learning such as observational conditioning and stimulus enhancement have been investigated in the context of social information spread between primates. However, not many studies have utilized such social learning mechanisms to study social learning between humans and artificial agents. In the work described here, we seek to understand if and how simple social learning mechanisms can influence human participants using an online game platform with an immersive first person experience built through Unity. Specifically, we designed a study inspired by experiments in behavioural sciences to investigate whether and to what extent, a robotic agent can influence human's actions. The study compared two conditions in which the robot showed body-language based emotions in a positive or negative manner that could enhance certain stimuli for the human participants and influence their decision making. From this, we wanted to understand whether these effects are socially learned by humans. Objective (position of player in-game) and Subjective (questionnaires) measures were recorded, and markers using the objective data suggest successful social transmission of information. We believe this approach can make a novel contribution to the field of Human Interaction with Artificial Agents.

1 INTRODUCTION

Social learning is the facilitation of learning by observation or interaction with another individual or its products (Hoppitt and Laland, 2013). While these interactions have typically been studied in humans and other social animals, certain recent literature has focused on social interaction among generalized agents that may be artificial, including robots (Steels and Kaplan, 2000) (Hamid et al., 2020).

Several mechanisms play a role in the learning processes that we see every day. Some of them have been termed cognitively more complex, requiring a greater amount of cognition such as imitation. Others are more simple and need not require complex perceptual and cognitive processes, but may involve a simple redirection of attention, local enhancement being one good example. In between these two levels of complexity lie a plethora of social transmission mechanisms with varying levels of cognitive complexity required. Mechanisms that were defined earlier in the literature and remain popular include Stimulus-Stimulus learning which includes Observational Conditioning, the mechanism identified behind Pavlov's famous experiments. Emulation is another mechanism that was identified earlier in (Hoppitt and Laland, 2013). However, while we know that humans can socially learn from other humans, they may also learn socially from non-human agents. Humans learn a variety of skills and behaviours through interaction with others, cf. language learning through interaction with others (Tomasello, 2009). Social signals can be non-verbal, or can involve vocal, non-speech signals. For example, vervet monkeys (*Cercopithecus aethiops*) use vocal calls for anti-predator alarm signals, even going so far as to classify which type of predator is hunting them (Seyfarth et al., 1980). However, such specialized signalling only works within a certain species, not across species.

So far, we discussed examples where communication happens within a species of primates. However, there do exist several instances of humans extracting or delivering information socially from or to

[a] https://orcid.org/0000-0002-8942-4621

Hamid, O., Chandra, S., Dautenhahn, K. and Nehaniv, C.
Social Transmission of Information through Virtual Robotic Agents.
DOI: 10.5220/0010823000003116
In *Proceedings of the 14th International Conference on Agents and Artificial Intelligence (ICAART 2022) - Volume 3*, pages 361-372
ISBN: 978-989-758-547-0; ISSN: 2184-433X

animals. In (Byrne and Tanner, 2006), this type of 'imitation' by an animal (a western lowland gorilla, *Gorilla g. gorilla*), who learns to reproduce observed actions, is considered simple priming where the animal puts together actions it already knows, and then reinforces them by individual learning. The gorilla in this experiment was able to 'imitate' gestures that humans showed her to the extent that naive coders who were asked to check if such actions resembled the original gestures by humans gave scores that confirmed socially learned behaviors. This particular form of learning, previously called gestural imitation, was termed in this study as *Response Facilitation*.

Complex cognitive processes can be involved in socially learning from others, in particular in the area of *imitation learning*. Large bodies of work have been developed on *Imitation* and *Learning by Demonstration* between robots and humans, where robots are being taught by human teachers. However, crucial perceptual and cognitive challenges remain to be resolved, and some of them are discussed in (Nehaniv and Dautenhahn, 2001). This serves as the inspiration for utilizing simpler methods of social learning so that robots and artificial agents are able to learn socially in human-agent interaction.

2 BACKGROUND

A number of efforts have been made to classify social mechanisms of information transfer in primates, and the definitions have changed over time. Some of the older efforts were made by Galef (2013), Heyes (1994) and Zentall (2001). The ones utilized here are more recent versions built on previous work (Hoppitt and Laland, 2013).

Several researchers have studied learning behavior among animals, where a *demonstrator* directs an *observer's*[1] attention to the specific location of a food object using simple attention mechanisms such as tapping the item with a body part or partially biting and chewing a strategically important part that needs to be exploited initially so that food acquisition by a 'naive' observer is made easier (Previde and Poli, 1996; Terkel, 1996). For example, in wild greylag geese, attention is drawn by tapping a certain location. This same effect can be had if a human taps a certain object in a specific place (Fritz et al., 2000).

In a classic study in humans, Gerull and Rapee (2002) have documented that affective responses to novel objects can be learned socially. Specifically, if humans observe something novel, they usually associate certain emotions to the newly introduced object of interest when they observe someone else who has more experience react to the novel object or situation in a certain way. In (Gerull and Rapee, 2002), toddlers, when first being introduced to novel toy creatures, learned to associate fear and avoidance behavior towards the objects when they witnessed their mothers reacting to the objects with fear, horror or disgust and avoidance. Toddlers reacted significantly differently when a mother's reaction was positive, not showing any avoidance to the toy physically. Facial expressions were also very different in the two cases, the children in the negative condition showing expressions of clear disgust or horror, while those in the positive condition treated the toy normally. This shows that the information provided by an experienced demonstrator (e.g. mother) is crucial to the perception of any object that the observer (e.g. toddler), hence creating a Stimulus-Stimulus pairing. Gerull and Rapee also found significant differences between the perception and avoidance behavior of male toddlers and female toddlers to the mother expressing a positive or negative emotion. Male toddlers were less avoidant towards the toy creature in the negative condition than female toddlers. Furthermore, the impression of these emotions lasted for at least up to 10 minutes, making this one of the first studies to understand potentially how long the effects might last.

This specific experiment is of great interest to us for a variety of reasons. New environments pose a challenging problem when humans who are naive to the environment first encounter challenges. An experienced agent that understands the subtleties and problems of an environment can pass on information to newcomers, gained by previously exploring this environment. We therefore envision situations when embodied artificial agents, quite specifically robots, introduce humans to a new environment efficiently. For instance, teaching humans about features and situations in the environment that are dangerous, and others that are harmless, even if they may appear dangerous. Our study therefore aims to draw inspiration the above-mentioned social learning study (Gerull and Rapee, 2002), in the new context of fostering *Agent Interaction and Communication* that can be beneficial to learning about a new environment that the human encounters. Note that the study by Gerull and Rapee is itself an extension of Cook and Mineka's series of experiments (the original experiments were conducted from 1984-1993, but a comprehensive review

[1]We use the words *demonstrator* and *observer* throughout the paper to refer to the agent 'demonstrating' a certain behavior in which it is already experienced in, and the naive agent receiving social information as an 'observer' respectively.

can be found in (Mineka and Cook, 2013)) which showed observational conditioning of fear of snakes among rhesus monkeys, using toy snakes.

2.1 Types of Social Learning

The process of Social Learning is rarely random or without reason. In fact, social transmission of information has been termed strategic. A very complete list of strategies for social learning can be found in (Hoppitt and Laland, 2013). Some of the most common reasons are "when" strategies such as copy when uncertain. For instance, naive rats copy other more experienced rats for their choice of diet (Galef, 1996). Historically, most sub-types of social learning have focused on imitation, with earlier work considering all forms of animal based social learning to be an attempt to reproduce human-like imitation (Hoppitt and Laland, 2013). However, other scientists have categorized the same behaviours as different types of social learning. Classification schemes for social learning mechanisms are broadly categorised according to the following: (1) context specificity (i.e. whether dependent on location or stimulus); (2) whether the outcome is sensitive to the demonstrator's actions; (3) whether the information being transferred is action specific and; (4) if the learned behaviour is a novel action sequence (Hoppitt and Laland, 2013, p. 99).

In our study, we are interested in understanding if social information can be spread by an emotionally intelligent robotic agent to a human, similar to how mothers' emotional reactions were transmitted to their infants (Gerull and Rapee, 2002). In doing so, we wish to establish a precedent on the effects that social behavior expressed by non-human artificial agents can have on humans.

In the kinds of observation based learning that were discussed above, certain specific types of social learning stand out and are described and defined as follows:

Response Facilitation (RF): is defined as the "*presence of a demonstrator performing an act [that] increases the probability of an animal which saw it do the same*" (Byrne, 1994, p. 237). As mentioned in Section 1, a good example is that when a demonstrator performs such actions, the observers have a "priming" effect. Note, this effect may be transient, i.e. the probability of the observers performing the same actions might reduce later in time.

Observational Conditioning: is one of the older mechanisms that was discovered through classical designs of social learning studies. The earliest studies in this category include Pavlovian conditioning where an *Unconditioned Response (UR)* to a stimulus for the demonstrator acts as an Unconditioned Stimulus (US), which then becomes a *Conditioned Stimulus (CS)* for the observer, and the observer will then respond the same way. Heyes' definition is a little broader in that stimuli need not be conditioned (Heyes, 1994). It is defined as "*a subset of Stimulus-Stimulus learning where an observer observing a demonstrator is exposed to a relationship between stimuli at t1 and the observer's behavior changes in a detectable manner at a later time t2*".

Finally, **Stimulus Enhancement:** as defined by Heyes (ibid.) occurs "*when an observer observing a stimulus at time t1 from a demonstrator and this stimulus causes an observable change in the observer at time t2*". Stimulus enhancement requires memory and learning, since the observer has to retain information about the object and how it was used, in order to use the same object in a different context, or a different object in a similar context(Giraldeau, 1997).

It should be noted that there exists plenty of overlap between the above-mentioned types of social transmission mechanisms. This is due to the reason that a combination of factors might be at play when we see certain types of imitation-like behaviors in animals.

2.2 Social Learning with Artificial Agents

Little research has been conducted on how artificial agents interacting with humans might shape or influence their experiences. This is specifically the case for non-verbal social information spread not including cognitively complex forms of imitation. A certain amount of literature review on social learning in robotics, specifically multi-agent robotics was conducted in (Hamid et al., 2020). Cakmak et al.'s work is one of the few examples that can be found of human-robot interaction with social mechanisms simpler than imitation (Cakmak et al., 2010). It investigates how different social learning mechanisms such as emulation, mimicking and stimulus enhancement (three other simpler forms of social transmission) can be used to teach robots certain simple tasks. Similarly, social learning was also utilized for basic language learning using the Aibo robot (Cakmak et al., 2010). While no specific type of social transmission mechanism was identified, social learning for language acquisition through a human mediator is realized through observational learning. Additionally, supervised and unsupervised machine learning algorithms were used for this task.

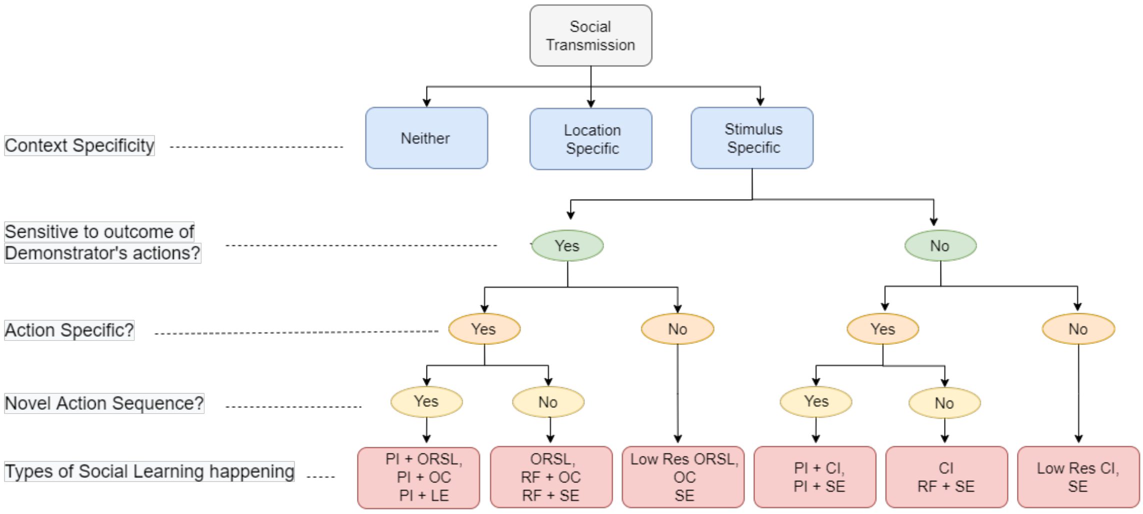


Figure 1: A decision tree describing which types of social transmission are at play depending on the effect of the stimulus and the demonstrator's actions, adapted from (Hoppitt and Laland, 2013). The social learning mechanisms are classified according to different levels: if the effect of the stimulus is Context Specific, if it is dependent on the demonstrator's actions, if the action itself plays a large role in the effect, and if the effect depends on an action sequence that is novel. PI = Product Imitation, CI = Contextual Imitation, ORSL = Observational R-S Learning, OC = Observational Conditioning, LE = Local Enhancement, RF = Response Facilitation, SE = Stimulus Enhancement.

In our work, we investigated simple forms of social learning mechanisms that could be transmitted by the artificial agents such as robots to humans. Additionally, we wanted to understand if robots are just as effective as experienced demonstrators in conveying social information to humans.

2.3 Using Virtual Environments as a Stand-in for Real World Experiments

Since the platform used for conducting this experiment is entirely virtual, using a game environment, it is worth asking whether this study can be emulated in real world conditions, and how close the study gets to evoking actual emotional responses from participants. The pertinent practical question being, can we compare emotional arousal in games to experiencing emotions in the real world?

While there are different opinions about the extent of the human reaction to events in digital media (including games and movies), (Reeves and Nass, 1996) pointed out that the responses to media events are remarkably similar to real world responses. While there is some agreement that the immediate emotional response is very similar, the longer term effects might be more blunted for virtual events. (Cantor, 2009) asserts that previous experiences do play a strong role in evoking emotional responses, especially from the real world, however in the virtual world these are less intense than the same happening in the real world. (Cantor, 2009) and (Lynch and Martins, 2015) argue that previous experiences may allow participants to cope with fear based scenarios more effectively and allow a more balanced reaction towards these events.

Given the current trend of artificial agents playing increasingly bigger roles in human society, understanding how these agents may influence humans is an important question to consider. We address this question by designing a virtual scenario where a robotic agent needs to guide a human who is new to the environment, assuming that these might be some of the roles given to intelligent agents in the future.

3 RESEARCH QUESTIONS & HYPOTHESES

Despite drawing inspiration from the above mentioned experiment that involves a mother transmitting social information to a child about a novel stimulus in the environment (Gerull and Rapee, 2002), several factors have been changed to better suite the study currently conducted. First, we focus on adults rather than infants because our use case, i.e. familiarizing individuals to new environments, suites adults. In the case of grown adults, they do not necessarily react to surprising stimuli in a new environment in a manner similar to how toddlers or infants react. For example, adults may have inherent biases from previous experiences that might make them more or less susceptible to either positive or negative actions. Second, adults are already used to a large variety of different objects and experiences, so it can be difficult to create truly novel stimuli that they previously have never encountered, making our task of replicating the experiment difficult. To counter this, we attempted to make the animal novel and thus chose an alien animal that is not common in general, does not exist in reality, and resembles a combination of two or three animals. Table 1 outlines the similarities and differences in our approach as compared to (Gerull and Rapee, 2002).

In this study we are interested in understanding if social information (in this case affective behaviour by a virtual robot) can spread to humans who share the environment (designed similar to a computer game) with the virtual robot. We study the role of simple social transmission mechanisms such as Observational Conditioning, Stimulus Enhancement and Response Facilitation. Figure 1 portrays the decision making process that allows us to narrow down these mechanisms.

The methodology of the experiment is described in detail in Section 4.1, however a functional description of the experiment is given here. The experimental design requires a novel stimulus in an environment unfamiliar to the participants, with a virtual robotic agent acting as a demonstrator. The game was designed such that a novel stimulus would startle the demonstrator (robotic agent) in a programmed fashion, with the observer constrained to watch the exchange in a virtual forest environment. The stimulus chosen had to be novel to some extent, therefore an "Alien Animal" was chosen for this task. The demonstrator reacts either positively [2] or negatively [3] to the animal, i.e. acting in either a friendly manner or running away in terror, respectively. All the while, the participant/observer watches this reaction of the demonstrator towards the novel stimulus without being able to move. The study used a between-subjects design, i.e. participants saw either the demonstrator's positive or negative reaction.

In this context, and with reference to the decision tree shown in Figure 1, the effect is stimulus specific, sensitive to the demonstrator's actions, action specific, but not a novel action sequence[4]. Thus, we are left with three possibilities to classify the social transmission that might occur in this study, namely, ORSL (Observational Response-Reinforcer Learning), RF (Response Facilitation) + OC (Observational Conditioning) or RF + SE (Stimulus Enhancement) which is the red box, second from left in Figure 1. In order to differentiate between these 4 types of social transmission mechanisms, two factors are important; whether the observer observes the demonstrator get rewarded for its behavior, and whether this learning is S-S (Stimulus- Stimulus) or R-S (Response-Reinforcer). From our earlier discussion[5] in Section 2, SE, OC and RF do not typically involve rewards[6]. ORSL can therefore be ruled out. This narrows down the possible social transmission mechanisms to either RF + OC or RF + SE. Further information is provided once the results are explained in Section 6.

We designed a between-subject study that aims to investigate the effect of a *robotic* demonstrator on an observer[7] in an unknown terrain, i.e. a virtual forest. These characteristics include two affective behaviours (positive and negative emotions expressed through body movements) portrayed by a robotic agent when encountering a novel creature. Note, in order to provide context for the demonstrator agent's skills, it is introduced as having prior knowledge of the environment, which is new to the observer. We formulated our research questions as follows:

- RQ1: Does the perceived reaction (positive, negative) of the demonstrator (robot) affect the observer's (human participant's) response? If so, to what extent?
- RQ2: Does the participants' gaming experience or gender affect their responses towards the creature? If so, to what extent?

With respect to these research questions, we propose the following hypotheses:

- **H1 for RQ1:** Distance of the participant to the animal in the positive condition should be lower than in the negative condition. We expect participants in the positive condition to have a more positive attitude towards the alien animal. In (Gerull and Rapee, 2002), children observe and infer the nature of the relationship between their carer and the

[2]The actions taken by the virtual robotic agent for the positive condition can be seen by clicking HERE

[3]The actions taken by the virtual robotic agent for the negative condition can be seen by clicking HERE . It is to be noted that the alien animal's actions were exactly the same in both conditions. Only the demonstrator's actions were changed. Further, care was taken to show the same actions by the animal in both conditions

[4]We assume that adult participants are fully capable of recognizing the demonstrator's actions. Hence, this effect is not based on a novel action sequence.

[5]A detailed version of these subtleties is discussed in (Hoppitt and Laland, 2013), Section 4.2

[6]There is some debate regarding usage of reward for OC, see (Palameta and Lefebvre, 1985). However, OC combined with RF may not necessarily involve rewards

[7]We use the word observer and participant interchangeably since in this experiment, the observing agents are the human study participants.

Table 1: Description of similarities and differences of the present study, as compared to (Gerull and Rapee, 2002).

	Gerull and Rapee	Current Study
Mean Age	17 months	30.6 years
Type of Social Transmission	Observational Learning	Observational Conditioning
Number of Participants	30	44
Gender of Observers	F-15, M-15	F-17, M-27
Demonstrator	Mother (Human)	Robotic Agent
Stimulus	Snake/Spider toy	Virtual Alien Animal
Measurement	Subjective - Likert Scale	Subjective and Objective
Number of times observer is exposed to stimulus	3 times 1st at 1 min, 2nd at 2 min, 3rd at 10 min	2 times 1st at 1 min, 2nd at 7 min

novel creature by recognizing disgust or fear, and replicating the same avoidance behavior towards these creatures.

- **H2 for RQ1:** Participants in the positive condition should have a more positive and less violent perception of the creature as compared to the negative condition.
- We do not present any hypotheses regarding RQ2 since the question for the effect of gender was only included because Gerull and Rapee found an effect, although this was for toddlers. We include the effects of gaming in the RQ since we would like to know if previous experience has a significantly different effect on a participant's behavior in-game.

4 METHODOLOGY

We used Amazon Mechanical Turk to carry out this remote study. The virtual environment is set in an unknown terrain (a forest). The game scene includes a virtual robotic agent capable of two types of emotional body expressions (positive, negative) portrayed by the robotic-like agent when subjected to a novel creature, with the robotic agent being depicted as someone with experience in the environment through the game narrative. For the participants, the goal of the game is to collect spheres scattered around the game world. The spheres were distributed around the environment in such a way that it would not bias participants towards either moving towards or away from the alien animal. The entire participant experience was divided into three parts:

- The pre-game Questionnaires: This includes some basic demographic information, consent and general information regarding the game. This was administered using Qualtrics© (2021 Qualtrics).
- The game experience included three levels:
  - Level 1: Familiarization phase where participants get used to the game interface using their keyboard and mouse on a PC/Laptop
  - Level 2: Participants explore the area, looking for in-game rewards. The event with social transmission where the robot reacts either negatively or positively to the alien animal happens then. Next, the animal is removed from the game (in accordance with the methodology followed in (Gerull and Rapee, 2002)). This level then continues for another 6 minutes, to make sure there is no immediate emotional carry-over to the next phase.
  - Level 3: The participant starts the game at a position where they observe the alien animal directly. The creature remains at the same position and does not move in space, it is simply looking around. The participants can now explore the area in the vicinity of the animal, as well as moving further away, picking up resources. This level lasts 7 minutes before the game is bought to a close.
- The post-game Questionnaires: A set of custom-made questions ask about participants' experiences during the game, notably their perception of the alien animal, and including a few questions as attention-checks. This questionnaire was also hosted on Qualtrics.

This study was approved by the Office of Research Ethics at University of Waterloo.

4.1 Game Development

The game was designed with the Unity 2019 editor. Participants were asked to enter their ID, and their in-game positions were recorded once every second. The game is hosted through the Web Graphics Library

(WebGL) format on Github pages. This allows the game to be hosted remotely and to be playable on a web browser without the user having to install any plugins, and multiple participants can play simultaneously. In-game data is stored on an external online DataBase based on a MongoDB server on the cloud.

4.2 Questionnaires

Two standardized and two custom-made questionnaires were included in the study and administered through the University of Waterloo's Qualtrics system, along with the accompanying consent form at the beginning, an explanation of the tasks, instructions to play the game and a web page explaining the exact purpose of the game at the end of the experiment. Custom-made pre-game and post-game questionnaires were completed by participants. Attention check questions were used to address some of the issues regarding Amazon Mechanical Turk studies such as lack of attention or misrepresentation (MacInnis et al., 2020) (e.g. Have you encountered the creature? How does the creature look like?). Other questions concerned participants' reaction to and perception towards the alien animal in relation to what they observed from the virtual robot demonstrator (e.g. How did you perceive the behaviour of the robot?).

4.3 Participants

A total of 49 successful participants were recruited on Amazon Mechanical Turk. Data integrity was important since there was some packet data loss through the three-step process with respect to the participants' position. In order to enhance the quality of the data collection, participants were recruited with respect to specific metrics (>96% completion rate for at least 50 previous tasks completed).

The participants were equally distributed according to the two experimental conditions. However, due to some participants failing the attention checks, the study finally had 27 participants in the negative condition and 22 in the positive condition. Of the 27 in the negative condition, 3 were excluded due to packet data loss regarding their location in-game. A further 2 were excluded due to low quality of submissions. A low quality submission was defined as the participant either standing at the same place for a long time (over 3 minutes of the total 6 minutes in the first level, hence showing inactivity), or answering the questionnaire by clicking on the same options for multiple questions. This left us with 22 participants for each condition, in total 44 participants, 28 males and 16 females, 19 to 55 years of age, with the mean age being 30.64, S.D. of 8.9 years, 32 gamers and 12 non-gamers.

4.4 Statistical Analyses

To understand the effect of social learning mechanisms on the participants, we collected the data in the form of objective and subjective measures. The objective data collected during the study in the second phase includes mean and absolute distances [8] from the participant to the alien creature, the frequency of returns of the participant (moving back towards) to the creature, and the time duration that the participants took to their first return to the creature. Since there is no way to directly measure (objectively) how a participant feels regarding the animal, we believe distance of the participant to the animal in-game represents a faithful marker regarding how wary they feel towards the animal. A 'return' is defined as the participant walking to a position where they can clearly observe the animal from a distance of 40 game distance units. 40 is chosen as the cut-off since the landscape consists of hills near the position of the creature where a participant might be behind one of them and therefore not directly have an animal in their line of sight despite close proximity. These distances are calculated for each participant in relation to the creature at different time points: 15 sec; 30 sec; 45 sec; 60 sec and 100 sec. Because the alien animal was not a real threat to the participants' in-game character and always stood in one place, participants became curious about the animal after about 100s and started wandering closer to the animal. Therefore, the important period was the first 100s of the participants observing the animal and deciding whether to move away or explore around the animal. We explored different time stamps from 15 to 100, but from 60s up until 100s, no difference in results is found. Table 2 describes the normality tests that were performed to determine whether a non-parametric or parametric test was required to test for significance differences between the positive and negative conditions. Shapiro-Wilk tests were performed to understand normality of the objective data. This test checks whether a distribution is *non-normal*, i.e. if $p<0.05$, the data is *not* normal. If the data is indeed non-normal, the Mann-Whitney U test was performed, and the independent-samples *t*-test on the data that were normally distributed.

The subjective data includes a question regarding the participant's perception of the behaviour of

[8] For mean distance, we averaged the distance of a participant to the animal up to a certain time interval, for example, 30 seconds. The absolute distance is the distance to the animal at that point in time, for instance, at 30 seconds.

(a) (b) (c)

Figure 2: a A screenshot of the game showing the robot introducing itself to the participant. A game world map in a circle can be seen on the top right. bThe Alien Animal that was present in the game world. c An overview of the world. The dirt paths can be observed crisscrossing the landscape, while towards the bottom left, an overhead view of the alien animal can be seen.

the creature. The question that the participants were asked was: *How did you perceive the behaviour of the creature?*. Two example responses were: "I perceived the behaviour as curiosity" and "It seemed violent". The responses of all the participants were classified into three categories of perceived threat: Mild, High and None. Two independent coders not involved in the study rated the responses of the participants according to the three categories. Cohen's κ was run to determine if there was agreement between the rater's judgement on whether the participants perceived high, mild or no threat from the alien animal. There was good agreement between the two judgements, κ = .726 (95% CI, .556 to .896), p ¡ .001.

One other pertinent question asked in the post-game questionnaire was about the participants' reactions when they *first* saw the creature. This is in reference to Level 2 (see Section 4) when the participants first saw the creature and the robot's reaction to it. The responses were one of [Run Away, Approach, Neither, Other] and this data was classified as Nominal, and therefore the Chi-Square test was used with z-tests for post-hoc analysis.

5 RESULTS

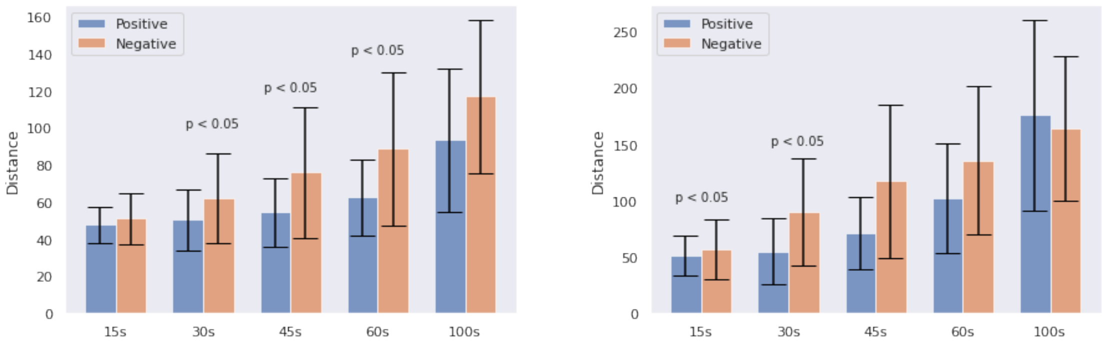
Mean Distance between Participants and Alien Animal: A Mann-Whitney U test was run to determine if there were differences in mean distance score between positive and negative conditions. Mean distance score at time point 30 sec, was statistically significantly higher in the negative condition (Mdn = 57.58) than in the positive condition (Mdn = 48.40), U = 152, z = -2.113, p = .035, using an exact sampling distribution for U (2-tailed). Similarly, at time points (for Mean distance) 45 sec and 60 sec, a Welch t-test was run to determine if there were differences in distance score between the positive and negative condition. The mean distance for the participants from the creature in the negative condition was higher (at 45 sec: M = 76.07, SD = 36.11; at 60 sec: M = 88.91, SD = 42.43) than the participants in the positive condition (at 45 sec: M = 54.49, SD = 19.00; at 60 sec: M = 62.64, SD = 21.12), a statistically significant difference was found for both time points 45 sec, M = 21.58, 95% CI [-39.31, -3.85], t(31.79) = -2.481, p = .019, d= -.52 (Moderate effect) and 60 sec M = 26.27, 95% CI [-46.89, -5.65], t(30.80) = -2.6, p = .014, d= -.55 (Moderate effect).

Absolute Distance between Participants and Animal: A Mann-Whitney U test was run to determine if there were differences in absolute distance score between positive and negative conditions. The absolute distance scores at time point 15 sec were statistically significantly higher in the negative condition (Mdn = 56.36) than in the positive condition (Mdn = 46.75), U = 153.50, z = -2.078, p = .037, using an exact sampling distribution for U (2-tailed). The absolute distance scores at time point 30 sec were statistically significantly higher in the negative condition (Mdn = 70.08) than in the positive condition (Mdn = 51.06), U = 175=4.00, z = -1.596, p = .013, using an exact sampling distribution for U (2-tailed).

Perceptions of Participants towards the Behavior of the Animal: With respect to the first impression of participants towards the creature, a chi-square test of homogeneity was run, with an adequate sample size established according to Cochran (Cochran, 1954). The two multinomial probability distributions were equal in the population, $\chi^2(3)$ = 8.581, p = .035. Participants in the negative condition were more likely to respond with "Run Away" (n = 19, 86.4% versus n = 12, 54.5%). Post hoc analysis involved pairwise

Table 2: Mean and Absolute distances of participants to the animal at 15, 30, 45, 60 and 100s. For Absolute distance at 60s, where the positive was normal and the negative non-normal, the Mann-Whitney was used, since both distributions need to be normal for the T-test. Here N- refers to Non-Normal, and N+ to Normal.

		15s	30s	45s	60s	100s
Mean	Positive	p<0.05, N-	p<0.05, N-	p>0.05, N+	p>0.05, N+	p>0.05, N+
	Negative	p<0.05, N-	p<0.05, N-	p>0.05, N+	p>0.05, N+	p>0.05, N+
Absolute	Positive	p<0.05, N-	p<0.05, N-	p>0.05, N+	p>0.05, N+	p>0.05, N+
	Negative	p<0.05, N-	p<0.05, N-	p>0.05, N+	p<0.05, N-	p>0.05, N+



(a) (b)

Figure 3: (a) The mean distance of participants to the alien animal up until 30s, 45s and 60s, respectively, showed a significant difference between positive and negative conditions. (b) The absolute distance of participants to the animal up until 15s and 30s showed a significant difference between positive and negative conditions.

comparisons using multiple z-tests of two proportions with a Bonferroni correction. Statistical significance was accepted at $p < .0125$. With the Bonferroni Corrections, there were no statistically significant differences in any of the cases. While the 'Run Away' response for Positive vs Negative Condition is statistically significant *without* the Bonferroni correction ($\chi^2(1)$=.021), with the correction this is still greater than .0125.
A Mann-Whitney U test was run to determine if there were differences in subjective rating scores between positive and negative conditions for the question "How did you perceive the behaviour of the creature?". No significant results were found for either of the raters' scores between Positive and Negative conditions.
Gaming Experience: Mann-Whitney U tests were run to determine if there were differences in the distances between gamers in the positive and negative conditions. No statistically significant differences were found for either Mean or Absolute distances. This was extended to Mann Whitney U-tests between gamers and non-gamers without regard for the condition they came from. No significant results were found for this test either.

A Mann-Whitney U test was also run to determine if there were differences in subjective ratings score between Gamers in the two conditions. No significant results were found for either of the raters' scores between the two conditions. Further, subjective rating scores between gamers and non-gamers was also non-significant.
Effect of Gender: The Mann-Whitney U tests were run to determine if there were differences in the distances according to gender. None of these data points for either Mean or Absolute distance were found to be statistically significantly.

Further, the Mann-Whitney U test to determine if there were differences in subjective rating scores between the self-reported Male and Female genders (no other genders were reported) found no significant results for either of the raters' scores between Male and Female participants.
Frequency of Return to Animal: An analysis was conducted to understand whether participants engaged in searching the area around the animal for rewards and returning to it. As before, the definition of 'return' was given as approach of participant to within 40 distance units, i.e. within observable distance.

A Mann-Whitney U test was run to determine if there were differences in the number of times participants return to the animal in the Positive and Negative Conditions. The statistic for frequency of returns was statistically significantly higher in the negative condition (Mdn = 1, Mean Rank=25.73) than in the positive condition (Mdn = 2, Mean Rank=19.27), U = 171, z = -1.722, p = .045, using an exact sampling distribution for U (1-tailed).

6 ANALYSIS & DISCUSSION

It is essential to interpret the results detailed in Section 5 within the context of the definitions provided in Section 2 and understand if the results support our stated hypotheses within the definitions laid out earlier.

Objective Measures for Positive & Negative Conditions: A closer look at the histograms in Figure 4 provides an interesting trend where we observe the distance of participants in positive condition (blue bars) to be less spread out and closer to the animal (higher towards the left side of the histograms), which represents a lower distance to the alien animal. This is visible more clearly for 30s, 45s and 60s in Row 1. The differences in the mean distances can be seen more clearly in Figure 3a that shows significant differences between the two conditions.

A similar trend emerges when we compare absolute distances between the two conditions. Histogram bars in Row 2 of Figure 4 show that participants in the positive condition are in higher numbers at shorter distances from the animal, i.e. there are more participants closer to the animal in the positive condition for at least 15s and 30s. This trend disappears as time stretches further. This means they tend to be closer to the animal during the earlier stages than the participants in the negative condition. We hypothesize that this is because participants start exploring the area more randomly in search of rewards as time goes on. The trend of significant differences between participants in the two conditions is shown in Figure 3b.

One other point of interest is the result from the frequency of number of returns, as presented in Section 4.4. This frequency was calculated to provide an understanding of how comfortable participants felt in searching for rewards closer to the alien animal. Assuming participants from the positive condition return to the animal more often due to having been exposed to a prior positive relationship, the 1-tailed test is significant. This *confirms Hypothesis 1 for Research Question 1*, i.e. the distance of the participant to the animal in general is significantly lower in the positive condition than the negative.

Subjective Measures: The subjective data that was collected with respect to independent coders' ratings of the threat level that participants expressed towards the animal was non-significant. While the results suggest that there is an effect of the demonstrator's (robot) reaction on the participant, these results are not significant. We hypothesize that this is due to hesitance among participants to admit fear in general, and they may not agree that they felt frightened even if their in-game behavior shows this. This means that *Hypothesis 2 for Research Question 1* cannot be verified. We consider subjective data to be supporting data, and secondary to the objective data.

Gender and Gaming Experience: A close look at the relevant Sections regarding previous gaming experience and effect of Gender in Section 4.4 show us that neither gender nor prior gaming experience made a significant difference in participants' attitudes towards the alien animal. Since no differences can be found between gamers and non-gamers for either the subjective or objective data, our data suggests that gamers and non-gamers have a similar experience in our study. Furthermore, gamers in the positive and negative conditions also do not seem to have had a very different experience. This is suggested by neither the objective nor subjective data for the positive or negative conditions being significantly different.

General: Taking the three types of objective data measures together suggests that participants in the positive condition tend to stay closer to the animal, and the only difference between the games played by participants in the two conditions is the type of reaction to the demonstrator.

With this in mind, referring back to the literature in social transmission among humans and other animals, Heyes' definition of Stimulus Enhancement (Heyes, 1994), where an observer observing a stimulus at time t1 causes an observable change in the observer's behavior at time t2, is satisfied. Further, it can be argued that the observer participants are exposed to a stimulus relationship (fear or positive reactions towards a stimulus, i.e. an alien animal) at t1, which then leads to a similar manner being adopted by the observers at t2, thus fitting the definition of Observational Conditioning as well. To provide support that Response Facilitation has happened, we have to show that the probability of an observer doing the exact same thing that it saw the demonstrator doing must increase. Two problems can arise while trying to conform to this definition. First, we cannot calculate the probability of adoption of the same action because we must first define what the 'same' action is. Second, we must demonstrate such a probability increases, which we cannot do since the repertoire of actions that the participant can take through the game is very limited. Hence, it is difficult to provide support for RF through our online experiment, and so this theoretical issue remains inconclusive and has to be investigated in future research.

Of particular importance to theories of fear acquisition, negative stimuli pairing created a negative impression that lasted over 6 minutes, which was the time given between Level 2 and Level 3. This means that the effect lasts at least 6 minutes and does not

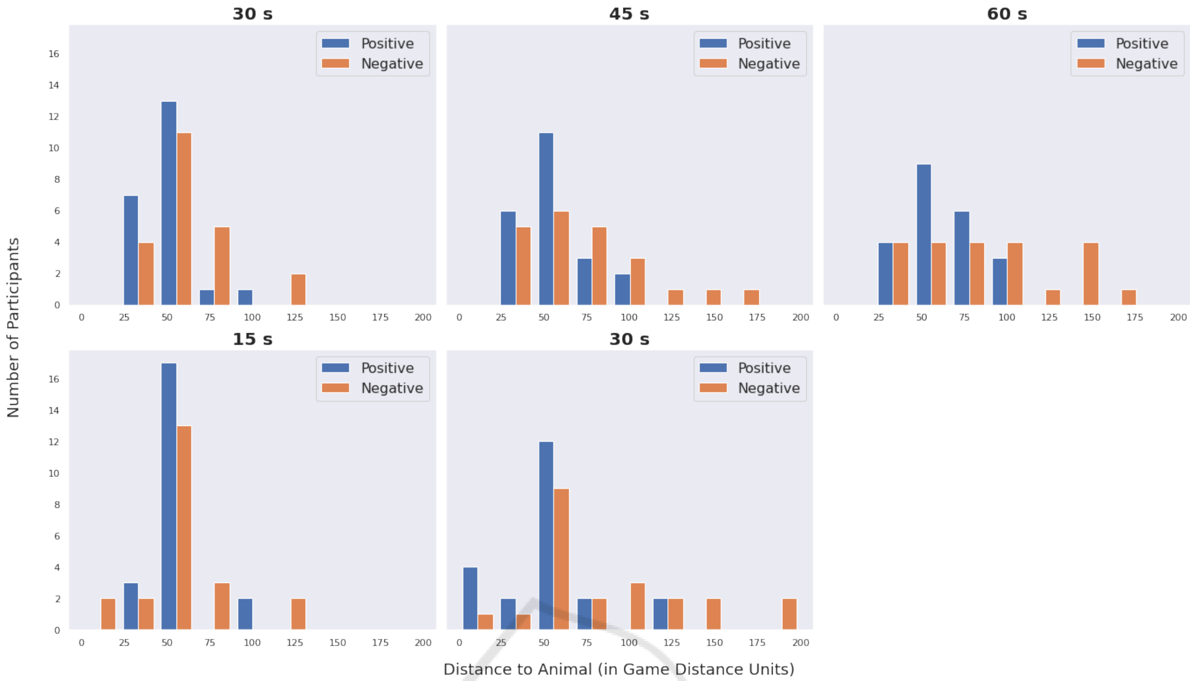


Figure 4: Row 1: The mean distance of participants to the alien animal up until 30s, 45s and 60s, respectively, showed a significant difference between positive and negative conditions. Row 2: The absolute distance of participants to the animal up until 15s and 30s showed a significant difference between positive and negative conditions.

simply disappear after the initial appearance of the alien animal.

As a comparison to the earlier study by (Gerull and Rapee, 2002), this study suggests the effect of Observational Conditioning and Stimulus Enhancement to last at least 6 minutes instead of 10 minutes in the earlier paper. The sample size for this study includes adults instead of children, is more numerous (44 versus 30), and is virtual in nature with an artificial agent as a demonstrator.

7 LIMITATIONS AND FUTURE WORK

The study is limited in nature for two reasons. First, it is very difficult to find other studies in human-human social transmission that can be replicated for Human Agent Interaction where the agent is artificial. Therefore, the scope is limited to suggesting that such types of social transmission are detectable and quantifiable. Second, while original plans to conduct this study were in person, the complete halt of in-person activities during COVID-19 forced this study to be conducted online. We would like to note that as is presented in Section 2.3, since virtual media and real world experiences are to some extent comparable, there is a good likelihood that the results produced in this study can be reproduced using real world scenarios. Therefore, these two limitations become scope for future work, i.e. the goal would be to conduct in-person experiments with real robots for human-robot interaction in order to verify the results gained in this remote study, and also to expand the studies to further incorporate other types of social transmission mechanisms. Certain other limitations in this study include unequal sample sizes regarding gender and gaming experience, which again was due to limitations of using crowd-sourcing methods, however, taken care of by the chosen statistical tests.

While two experimental conditions were studied here, it would also be desirable to compare these two conditions with a neutral condition. While we drew inspiration from (Gerull and Rapee, 2002) who compared only the positive and negative conditions, others (Mineka and Cook, 2013) utilize the approach with a neutral condition as well. Finally, variations of the virtual environment, tasks, and the nature of the demonstrator (e.g. whether a robotic or human-like or animal-like agent) could be studied further. All of these factors make for exciting possibilities to conduct future work.

8 CONCLUSION

An online study was designed to understand if simpler forms of social learning (i.e. simpler than imitation) can be observed between artificial agents and human participants being present in a virtual, game-like experimental environment. Results from objective and subjective data collected during the online game, which was carefully designed to perform stimulus pairing, point towards successful social transmission between a robotic virtual agent and human participants of information utilizing a mixture of methods, as identified in the literature as Observational Conditioning, Stimulus Enhancement and possibly Response Facilitation. The study closely emulates work done previously in the form of mother-child interaction, (Gerull and Rapee, 2002), and to some extent, human-animal interaction (Mineka and Cook, 2013). Neither gender nor previous gaming experience seem to play any significant role in the efficacy of social transmission of information in our study.

The study, to the best of our knowledge, is a novel approach in the field of Human Interaction with Artificial Agents, inspired by experiments in behavioural sciences. Further studies with in-person participation and real robots would be beneficial, once such research is possible, to verify and extend the results.

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