This experiment suggested that by following the design considerations described in our case study, users' perception of the social presence of the artificial opponent improves.

RELATED WORK

Social presence was initially proposed by Short, Williams and Christie [30] as "the degree of salience of the other person in the interaction and the consequent salience of the interpersonal relationships". The social presence theory allows researchers to guide the design, and to anticipate and measure differences of new types of social technology. Instead of using trial and error exploration, a better understanding of what social presence is can save valuable time and money, and can improve the end product in the design of new media technologies [20]. Many studies regarding social presence are found in new techniques of human-human communication such as computer conferencing. However, social presence is also used to measure an individual's perception of a particular interactive medium, be it a virtual reality environment [31] or the interaction with a social robot [18].

Several authors have discussed factors that influence social presence, but none of the authors have previously focused on artificial opponents. In the remainder of this section, we collect the factors that are deemed important for creating socially present artificial agents and opponents.

Contributing Factors for Social Presence

There are different modes of interacting with a virtual agent, but in terms of social presence, *face-to-face interaction* is still considered the gold standard in communication against which all platforms are compared [1]. Social presence is assumed to be highest when two people are within reach of each other and are interacting on a task [4]. Therefore, virtual agents that do not use the rich set of social behaviours and cues involved in face-to-face interaction may be considered less socially present. Face-to-face interaction is generally accompanied by *verbal communication*. While interacting with virtual characters or robots, verbal communication offers the most attractive input and output alternatives. We are familiar with verbal communication, it requires minimal effort from users and it leaves their hands and eyes free [34]. Interactions should also feel natural and quick. Systems should have *quick feedback* for the user to feel immediacy of control, as delays between actions and reactions can diminish the sense of social presence [20]. In robots or on-screen characters, having a responsive real time gaze system can produce a high sense of agency and increase the agent's perceived social presence [35].

The *number of interacting entities* (be they virtual agents or humans) can also positively influence the perception of social presence in an interactive system. Having more than one entity in media interactions can be an easy way to induce a sense of social presence, regardless of the other perceptual features of the world [11]. *Knowledge and prior experience* with the medium also influences the sense of social presence. Social presence varies across individuals and across time for the same individual. When we have been exposed to artefacts of a particular medium over time, we have a higher knowledge of

interacting with it, and it is possible to have an increased feeling of social presence. However, very often, continued experiences may cause the well-known habituation or novelty effect [14]. This effect causes an initially higher sense of social presence that fades away as users become more experienced with novel technology [18]. This novelty effect is present in almost all types of media, including artificial agents or robots [8]. The ability to attribute mental states to oneself and to others is fundamental to human cognition and social behaviour [32]. Biocca [4] stressed the importance that the *theory of mind* has in social presence. He defines social presence as the sense of "being together with another" and attributes this sense to the ability to relate to or to construct mental models of another's intelligence. These models can simulate minds of people, animals, agents, aliens, gods and so on. If we interact with an agent and create a mental model of it, we can anticipate the agent's behaviour and judge its consistency. The number and quality of sensory channels are important for generating a sense of social presence. More importantly, *consistency* between all of the different modalities is one of the most relevant keys for achieving social presence: "the information received through all channels should describe the same objective world" [20]. If we do not meet this criterion, we emphasise the artificial and lessen the feeling of social presence. Correlations between actions and reactions should be credible when compared to events that would be expected in reality under similar circumstances. Slater [31] notes that another important factor for social presence is the occurence of some events not directly related to the users' actions. These events show *autonomy* in the environment or character. In a study conducted in a cave-like environment, participants spent approximately five minutes in a virtual bar interacting with five virtual characters [7]. Participants were reported to automatically respond to the virtual characters present in the bar in social ways. Though these virtual characters had limited social behaviours, mutual gaze combined with lucky randomness, was perceived by participants as the characters watching and mimicking them. *Embodiment* is also important for designing a computer to achieve a higher sense of social presence. It has been reported in virtual poker environments that the simple addition of a picture personifying players made the game more likeable, engaging and comfortable [16]. We can also find examples where physically embodied agents (or robots) are used to simulate opponents. It was shown that by using a robotic embodiment instead of an on-screen character, artificial opponents have improved feedback, immersion and social interaction [23]. We use our emotions in our social world almost constantly.

Emotional responses can elicit adaptive social responses from others. For example, someone with an angry temperament can elicit a fear response from someone else, while someone distressed may elicit an empathic response from others. We also use emotional expressions for communication, signalling and for social co-ordination. These types of natural social primitives can be interpreted by humans without the need to learn something new; a human-like computer using these cues can cause social facilitation in users. Endowing agents with *emotional behaviour* can contribute to the believability of a character and thus to its perceived social presence.

extracted and that categorisation helps pinpoint the most important social behaviours to simulate in a Risk game. Additionally, in that study, a database of possible utterances was extracted from real human social behaviour. However, to understand the humans' thought process and to know when an artificial opponent should select a particular move or utterance, a protocol analysis was performed. In this analysis, participants were asked to think aloud while playing a traditional Risk game, and the most relevant variables to simulate in a social Risk opponent were extracted. In this sub-section we briefly describe the empirically extracted variables that enable the artificial opponent to establish different social relationships with different users: *Familiarity*, *Like/Dislike* and *Luck Perception*. These variables are used for generating dialogue or for choosing the next move.

Familiarity can be an important variable to model in a social agent because the number of utterances that an artificial agent can speak is often limited, and long term studies have shown that repetitive behaviours decrease social presence and believability [18]. Therefore, it is advantageous for an artificial agent to be shyer (less talkative) towards players with whom it has interacted for only a limited time and to become more familiar (talkative) with them over time. By implementing this behaviour, we are also following empirical results showing that when players already know each other outside the game or when they have played previous games before, they are more communicative and more willing to establish alliances between themselves. In our implementation, familiarity starts at a minimal value, never decreases, and increases slightly every time the robot interacts with players or every time a player interacts with the robot.

Influenced by attacks in the current and previous games, another relationship variable was simulated. This variable can be either positive (like), zero (neutral), or negative (dislike) for each of the agent's opponents. The agent can act socially according to this variable and establish different social relationships with different users. The variable changes after relevant game events; a change can be positive or negative. When players are not attacking each other, they are nicer to each other, and the opposite occurs when they attack. Thus, when a player attacks the agent, the relationship variable towards him/her decreases. The variable increases slightly when players have the opportunity to attack the robot but do not. The variable also changes when an opponent attacks a player the agent likes or dislikes. We took inspiration for this behaviour from Heider's balance theory [12]. Following the balance theory rationale, when a player is attacking one of the robot's "most hated" opponents, the Like/Dislike variable towards him/her increases. Conversely, if a player attacks one of the agent's "friends," the relationship variable will decrease. As previously reported, the Like/Dislike variable is stored, so the robot can disclose, for example, that it holds a "grudge" against a particular player because of previous games.

Luck perception is also stored in memory, so the agent can assess and comment if a player is lucky or if he/she was lucky in previous games. Risk is a game that involves lucky dice throws, and players are constantly "storing" in memory the luck that they attribute to other players. When players are lucky and constantly winning at dice throws, other players expect them to continue winning and usually comment on that fact. When the unexpected occurs and players lose after a winning or losing streak, stronger verbal and nonverbal reactions are usually elicited. Due to the frequency of verbal and emotional content commonly found in this game event [24], such behaviours seem to be important to implement in artificial agents that play games involving luck. Simple rules and statistics were used to monitor players' luck in the game. Luck events are generated by using an anticipatory mechanism [21] that assesses the mismatch between the agent's expectations of a dice throw and the actual result.

Risk is a highly social game that supports various social roles in its game play. Players can change roles throughout a game. Social roles in board games were identified by Eriksson et al. [6]. In our implementation, these roles arise because the robot's AI uses the relationship variables to influence its social behaviour. For example, when the agent "likes" another player, it often demonstrates the social role of Helper by making encouraging comments such as "It went well this turn!". Conversely, when the agent has a negative relationship with another player, it is more likely to adopt the Violator role, for example by attacking him/her without seeking any in-game benefit.

Multiplayer Gaze System

To achieve believable face-to-face interactions, we developed a gaze system that equips our robot with the ability to simultaneously interact with multiple players in our gaming context. The gaze system uses speech direction detection, face detection, and the context of the game; it is based upon studying how humans behave in such context. We have extracted gaze patterns and created a gaze system for multi-user interaction with a social robot. The gaze system is influenced not only by the robot's own variables but also by the other players' voices and game actions. The robot also uses a camera in its "nose" for face detection and uses sound direction detection sensed from the Kinect's microphone array.

In most board games, players shift their focus between looking at different parts of the board and looking at other players. Players look at the game board when they are thinking, during their own turns and their opponents' turns or when other players make their moves on the board. When it is not a players turn, they tend to look at the active player more than any other. We noted that the factor that most influences the amount of time that participants look at the board or at other players is their concentration on the game. Inspired by this observation, we modelled these behaviours in our robot by using a *concentration* variable. This variable enables the robot to look more focused on the game during its own turn and more focused on the other players during their turns. The variable tends to be higher during the robot's turn and lower during an opponent's turn. It also decreases when other players take too long to play or when all of the events in the game are not related to the robot's game.

Once a gaze command is over or is interrupted by a relevant event for the gaze system, another gaze command is issued. When it is not the robot's turn, it performs a Concentration Test (CTest). The CTest starts by generating a random value. If that value is less than the robot's current concentration variable, the robot issues a focused gaze action. If the value is higher, it issues an unfocused gaze action. This means that if the concentration variable is low, the robot tends to be unfocused, and when the variable is high, it is more often focused. When unfocused, the robot looks at other players randomly but with a higher probability of looking at the active player. When the robot issues a focused gaze action, it looks randomly at a point on the game board, simulating that it is thinking and looking at the game action attentively.

When a user touches the interface, the robot is informed of the location of the touch, and the robot is able to gaze at it. The robot can look at points on the interface precisely. To implement this, the robot is always fixed on the same predetermined position on the digital table; parametrised gaze values were calibrated for each point on the interface. If after a touch event the robot passes a CTest, it gazes at the interface. If the CTest fails, the event is ignored. This simulates the observed behaviour that when players are thinking they are more focused on the game board.

To further improve the robot's gaze system, we found the need to implement a speech direction detection module in the robot to make it look at players when they are talking. This module was implemented by using Kinect and its beamforming algorithms from the Microsoft SDK. The Kinect microphone array reports the position of the speaking player, and we use that angle to look in the direction of the sound. However, the robot only chooses to look in the direction of speech if it fails a CTest, simulating that it only "listens" to other players when unfocused.

Finally, when the robot decides to speak to a player, the gaze system also causes the robot to look at the direction of the intended player. All gaze actions belonging to the "look at a player" group work in the following manner. First, the robot looks at a position where the player most likely is. This initial probable position was calculated by several user tests in which we fixed gaze values for looking at the three human players. Second, once the robot fixes its gaze on that position, it tries to detect a face using EmguCV[2]. If successful, it tracks the user's face and follows it for the remaining time of the gaze action. Finally, to increase accuracy, the robot stores the last position of that opponent, remembering the probable position for that user for the next time.

Every gaze action stays focused on the target, be it a player or a point on the interface, for a determined amount of time. The only exception is when speaking to a player, the robot directs its gaze to that player until it stops speaking. For every other type of gaze, we have defined a minimum and a maximum length of time, and a minimum and a maximum of gaze speed. When the robot initiates a new gaze order, it uses random values both for the speed and gaze duration between those

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[2] http://www.emgu.com/

minimum and maximum values. We fixed high speeds and shorter time spans for events in which the interface is touched or a speech direction is detected. Slower gaze speeds and longer time spans are used when the robot is inactive.

EVALUATION

In this paper, we hypothesise that an agent that follows guidelines for socially present board game opponents will be perceived as more socially present than an agent that does not implement such guidelines. For testing this hypothesis, we report a study between subjects where participants played a Risk game against a robotic opponent.

Participants

Forty five participants (12 males, 33 females) with ages ranging from 18 to 40 years old ($M = 24.0$, $SD = 5.0$) took part in the experiment. Participants were undergraduate and graduate students recruited via a program in which they received extra curriculum credits for their participation. The experiment was conducted at a Psychology University. Each session included three participants.

Procedure

At the beginning of each session, participants were told that they were going to play the Risk board game against a physical robot and each other. We used a Powerpoint presentation alongside the interface of the game to explain the Risk rules and the game interface. A sequenced presentation was used so that every participant learned the rules and how to interact with the game interface in the same manner. The three participants then sat around the digital table with EMYS, our social robot, on the remaining side. EMYS acted as an artificial opponent for thirty minutes or until it was eliminated from the game. When EMYS was eliminated or the thirty minutes were over, EMYS warned participants that the interaction had ended. Finally, participants filled in a questionnaire, and the experiment was over. Each experiment lasted approximately 1 hour.

Manipulation

The experiment had two main conditions: a socially present condition (SP) in which we used the full implementation of our social opponent, and a less social condition (¬SP) in which the behaviour of the robot was not inspired by the guidelines for creating socially present opponents. We assigned 27 participants (9 groups of 3) to the SP condition and 18 participants (6 groups of 3) to the ¬SP condition. When recruiting participants for this study, we requested good English skills as a prerequisite. However, two participants in the SP condition were removed from the study (1 male and 1 female) because they reported in the questionnaire and to the experimenters that they did not have the English skills necessary to understand EMYS.

Socially Present Condition (SP)
Our experiment had the limitation of a single 30 minute interaction with the robot. Given this time constraint, we decided to fix some of the agent's variables to have a more controlled experiment and for users to experience the same diversified

lines can be used to create new forms of computer entertainment and to evaluate whether they indeed improve an artificial agent's social presence, we developed and evaluated a case study. An experiment was performed in which 45 participants played the Risk board game against an artificial opponent. The evaluation suggested that by following guidelines for creating socially present opponents, the users' perceived social presence towards our artificial opponent improved. We have no measure to exactly determine the success of each individual guideline. However, we can relate our results to each guideline.

Be physically embodied and be able to engage users in face-to-face interactions. Previous studies have shown the importance of a physical embodiment in an artificial opponent. The artificial opponent was therefore physically embodied in both of our conditions. However, when comparing both social conditions, our results suggest that the face-to-face interactions provided by the use of our gaze system contributed positively to the sense of presence. To further investigate differences in face-to-face interactions between conditions, facial videos of all the participants were retrieved during the experiment. For future work on this subject, a more detailed analysis using video annotations will be performed.

Exhibit believable verbal and non-verbal behaviours. By examining initial empirical studies on the target game and by carefully using those data in the implementation of the case study, we could create believable behaviour in terms of dialogue, game choices and emotional reactions. In the qualitative responses of the final user study, participants often argued that the robot's behaviour was adequate to most situations and that the behaviours were displayed in a timely manner. Additionally, there were significant differences in the dimensions of perceived message understanding and behaviour interdependence, these showed that applying data extracted from a verbal communication study and protocol analysis helped us create believable verbal and non-verbal behaviour that was displayed in a timely manner.

Comprise an emotion system. Our emotion system is composed of several variables that influence the artificial opponent's move selection, utterances and emotional behaviours. These variables, inspired by psychology models of appraisal, the human thought process while playing Risk and previous work on socially intelligent agents, seem to be sufficient for users to perceive the robot as an emotional/social being. Some participants claimed that the robot would become angry if they attacked him. Others said that he became sad when losing ground. These answers, along with significant differences in perceived affective understanding and emotional interdependence on the social presence questionnaire, indicate that participants believe that the robot played according to his emotional state and displayed coherent emotional behaviour throughout the game.

Have social memory. This guideline is of extreme importance in multiple interactions with the same participants. Although the implementation that we propose for an artificial opponent is prepared for coherently maintaining a relationship with a user throughout several interactions, our evaluation covered the span of only one interaction with each user. In the future, a longer-term evaluation should be performed. Nevertheless, participants still enjoyed and valued the robot's ability to call each participant by his/her name, and most participants in the socially present condition acknowledged that the robot established social relationships with them by remembering past actions in the game.

Simulate social roles common in board games. In the evaluation, more specifically in the socially present condition, the artificial opponent clearly expressed different social roles that were recognised by users. The robot expressed roles such as violator or dominator to players it did not like, for example, by threatening and attacking them more frequently. It frequently expressed the social roles of motivator and helper towards players it liked. By looking at participants' qualitative answers, we can also say that participants perceived the agent's social roles.

There is still much work to do before achieving a truly socially present artificial opponent or agent. However, by following guidelines and by taking inspiration from the case study that we have created, we believe that the next generation of artificial board game opponents or agents that are perceived as socially present can be created.

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