Believable Interactions Between Synthetic Characters

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Resumo

É frequente a necessidade do jogador humano de interagir e cooperar com personagens sintéticos, que por sua vez também interagem e cooperam entre si. No entanto, a não ser que a acção seja estritamente linear e parametrizada, a expressão de interacção é muitas vezes confusa, e de difícil leitura para o jogador. Este trabalho explora a forma em como os princípios de animação tradicional podem ser aplicados à expressão de interacção entre actores, tanto sintéticos como humanos, e tornar a comunicação e a cooperação mais credível e a experiência mais imersiva. Para validar o nosso trabalho, implementámos o nosso modelo num jogo multi-jogador de desporto, no qual cada personagem é um jogador artificial, e pedimos a participantes que vissem vídeos das interacções e respondessem a perguntas relacionadas com os vídeos. Os dados que recolhemos sugerem que a nossa abordagem não só melhora significativamente a credibilidade como também torna as interacções entre os agentes mais fáceis de compreender e a acção mais fácil de interpretar.

Palavras-Chave: credibilidade, interacção entre agentes, videojogos, intenções, antecipação.

Abstract

The human player is often required to interact and cooperate with synthetic characters, which also cooperate and interact with each other. However, unless the action is tightly linear and scripted, the expression of interaction is often confusing and difficult to understand by the human player. This work explores how traditional animation principles can be applied to the expression of interaction between the actors, both synthetic and human, and make the communication and cooperation more believable and the experience more immersive. To validate our work, we implemented our model in a multiplayer sports-game, where each character is an artificial player, and asked participants to evaluate videos of the interactions. The data we collected suggests that our approach not only significantly improves believability, but also makes the interactions between agents easier to understand and the action easier to interpret.

Keywords: believability, agent interaction, videogames, intentions, anticipation.

Dedication

To my dear mother. This is to you.

Acknowledgements

First and foremost, I would like to thank my parents for their investment and support in my studies and in my development as a person. I know how much you sacrificed.

Thank you Inês for your support along this journey. We have been partners in crime since we met each other. You believed in me when I didn't and you helped me in my darkest times.

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Chapter 1

Introduction

High profile games keep pushing the boundaries of their supporting hardware as far as visual fidelity goes. Their strive for believable environments and for photo-realistic presentation is relentless. It is hard not to be amazed when playing a game such as Call of Duty Ghosts[1]. Its frenetic campaign features impressive, over-the-top scenes on par with Michael Bay's[2] most famous setpieces! The player has the strong illusion of cooperation with his synthetic team-mates, and the enemies seem very clever. However, this approach works because the action is very linear and highly scripted. Generally, in open-world games that feature companions that interact with the human controlled characters - such as in Skyrim[3] or Fallout: New Vegas[4] - such attention to detail is usually lacking, and often we have trouble cooperating with these synthetic characters. As a result, the battles - which are critical aspects of these action-adventure games - come out as overly simplistic and mechanical. In Fallout: New Vegas, for example, you have the companion wheel from which you can manage the stance of your companions during battle. Unless the companion is a programmable robot, this doesn't seem like a very natural way to engage with your synthetic team, even if you were the commanding officer.

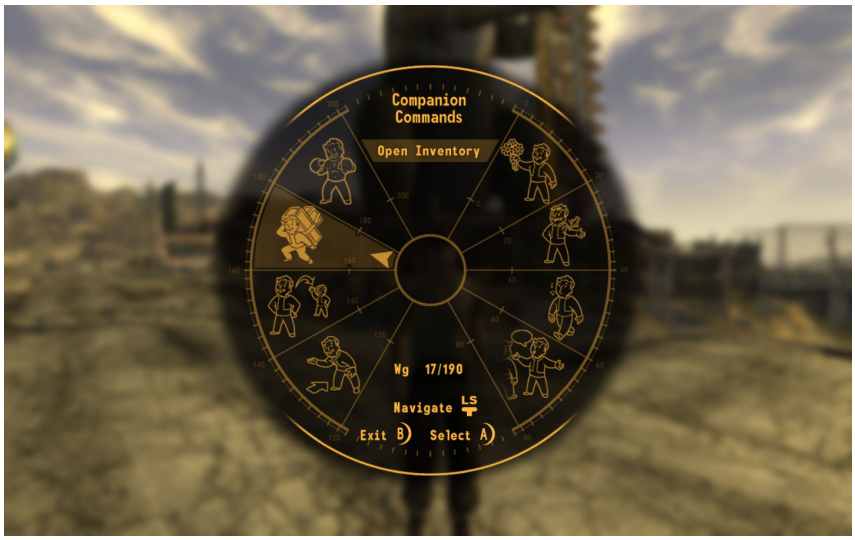


Figure 1.1: Companion wheel (Image from Fallout: New Vegas, Bethesda Softworks)

[1]Call of Duty: Ghosts. 2013, Infinity Ward, Activision.

[2]Michael Bay - American film director best known for high-budget action films such as the Transformers (2007-ongoing) film series

[3]The Elder Scrolls V: Skyrim. 2011, Bethesda Game Studios, Bethesda Softworks. `http://www.elderscrolls.com/skyrim`

[4]Fallout: New Vegas. 2010, Obsidian Entertainment, Bethesda Softworks. `http://fallout.bethsoft.com/`

BioWare[5] games are particularly well known for their ability to engage the player emotionally with his synthetic team-mates. Each companion usually has its own background story that reveals itself as the game progresses and as the relationship with the human player improves. It is also possible to engage certain companions romantically. By doing it the player may sometimes gain perks, for example, the companion may get stronger because of the romantic link with the player. Still, the biggest reward is the emotional connection experienced which makes the player even more invested in the game and in its story. For the experience to be most effective, consistency is required, and at all times the player should believe that he is interacting with other intelligent creatures and not predictable algorithms. However, the movie like experience is not brought to the combat scenes these games deliver, and the believable communication and interaction needed to cooperate effectively, as one would expect in this situation, is lacking.

1.1 Motivation

If we observe great action flicks we observe a whole level of interaction and cooperation between characters in the action setpieces. In the box-office hit *Top Gun*[6], we see permanent communication between the characters in the dogfights and we are aware of their intentions and strategies. The final stand in Spielberg's *Saving The Private Ryan*[7] is another great example. It is as if the action scene is a story within a bigger story that is the movie, in such a way that the viewer can describe it as a relevant part of the drama. As such, the status quo regarding interaction and cooperation between synthetic characters in battles in adventure video-games is clearly hindering their approach for a cinematic experience.

Action/adventure isn't the only genre where believable communication and cooperation is needed. In sports games such as the Fifa[8] series, players often complain about moments in the game where poor behaviour by the AI breaks the immersion and frustrates the player. This is particularly true in the Career Mode, where the player is given control of a single character, and must work is way up to the starting eleven of his club and the national team. Unlike the other game modes where the player is given control of the whole team, alternating between each player depending on the circumstances - such as distance from the ball, and always controlling the player of his team in possession - in this game mode the player has to rely heavily on his teammates judgement. In the real world football, there is constant communication happening: The coach corrects his pupils positioning, the players shout and gesticulate to each other to ask for the ball, a run from a teammate, to express their intentions, and to warn each other about the presence of a dangerous adversary or play. In Fifa 14 however, the player can request the ball, request a shot at goal, or to pressure the opponents in which the teammates blindly and unrealistically oblige, but cannot express his intents and neither can his synthetic teammates. This form of indirect control over the teammates is, in our perspective, not good enough. Moreover, if a player chooses to let his teammates decide by themselves, it is anyone's guess what's on their minds, alienating the player from a useful role in the context of the team, once again detracting from the experience and frustrating the player.

[5]BioWare. Canadian videogame developer best known for the Mass Effect (2007-ongoing) and Dragon Age (2009-ongoing) series. `http://www.bioware.com`

[6]Top Gun. 1986, Tony Scott, Paramount Pictures. `http://www.imdb.com/title/tt0092099/`

[7]Saving Private Ryan. 1998, Steven Spielberg, DreamWorks Pictures (US), Paramount Pictures (international) `http://www.imdb.com/title/tt0120815/`

[8]FIFA. Annually, 1993-present, EA Sports, Electronic Arts. `http://www.easports.com/fifa`

1.2 Believability vs Realism

First and foremost, we must dissipate the ambiguity there is between the concept of *believability* and *realism*. Though these concepts are often used as if they were synonymous with each other, it is important in our work to draw a clear distinction so the evaluation won't suffer due to the ambiguity.

The *thefreedictionary.com* defines *real* as[9] *Being or occurring in fact or actuality* and *True and actual; not imaginary, alleged, or ideal*. Based on this definition, one may say that the character *Mickey Mouse* isn't very realistic, as there is no such thing as a standing, talking mouse in real life. Walt Disney surely wasn't aiming for a realistic representation of a mouse with his emblematic creation. But, through the talent of Disney's animators and storytellers, kids all over the world are able to believe in those stories and emphasize with those characters as if they were real. Bates and Loyall argue that, the best way to achieve believability often involves, in their own words, "careful, artistically inspired abstraction, retaining only those aspects of the agent that are essential to express its personality and its role in the work of which it is part"[7].

According to Ortony[8], coherence and consistency are crucial elements of believability. The suspension of disbelief doesn't break if *Goofy* falls from a 20 meter building and get up unharmed, because it is consistent with the fantastic world that was created. On the other hand we get briefly pulled from the experience if we notice that, in *Lord of the Rings: The Fellowship of the Ring*[10], Frodo's sword, Sting, doesn't glow blue in certain scenes due to the the proximity of Orcs like it was supposed to due to a goof by the filmmakers. In fact, being consistent is the key to believability. A believable approach may be the realistic approach in some cases though. For example, *Grand Theft Auto V*[11] features a realistic open world city, with realistic characters walking and driving around the city, minding their own business just like one would expect in the real world. Can you imagine how awkward would it be if the player would start shooting in the streets without the NPCs starting to panic?

1.3 Believable characters in video-games

There have been attempts to improve the interaction with companions, Dragon's Dogma[12] for one, brought us an interesting yet flawed approach. You can team-up with pawns which are human-like creatures that lack emotion or will of their own (how convenient!) but are set to follow and aid the Arisen, which is the human character. The pawns learn about their surroundings and also the enemies weaknesses and vulnerabilities, but oddly they do not remember sharing it with the player, so the player ends up constantly hearing the same remarks such as "Wolves hunt in packs" or "It hates fire", and many others whenever it encounters common enemies, remembering him that these pawns are just synthetic agents with technical limitations and not true brothers-in-arms. The main interesting aspect of these pawns is, in our opinion, the inclination system - the pawns have nine possible inclinations, which are attributes that will dictate how the Pawn will behave. The player's main Pawn' starting inclinations are initially set after the player answers a brief questionnaire, and, after that, it is the player behaviour and his interaction with the Pawn that will influence its inclination. So, if a player is continually using the "Go!" command, the main Pawn will become more aggressive or adventurous. Conversely, the "Help!" command will influence the Pawn to be more of a support character that defends the human player,

[9] `http://www.thefreedictionary.com/real`

[10] The Lord of the Rings: The Fellowship of the Ring. 2001, Peter Jackson, New Line Cinema. (based on the novel The Fellowship of the Ring, by J. R. R. Tolkien.) `http://www.lordoftherings.net/`

[11] Grand Theft Auto V. 2013, Rockstar North, Rockstar Games. http://www.rockstargames.com/V

[12] Dragon's Dogma. 2012, Capcom, Capcom. `http://www.dragonsdogma.com`

heals him and keeps him safe. Also, the Pawn can enchant the human player's weapons making him stronger, but it is as far as it goes regarding cooperation.

Figure 1.2: Let me guess: It hates fire? (Image from Dragon's Dogma, Capcom)

Another interesting approach was BioShock Infinite's[13] Elizabeth. She serves as a companion to the human player and is a central figure to the main story. Elizabeth's attention is constantly being drawn to the environment around her - which she's experiencing for the first time - instead of simply focusing on the player's action like a robot. In fact, she's frequently interacting with other non playable characters (NPCs), examining items, expressing compassion about the poor and the victims of the distopian world she's discovering, joy as she walks on a beach for the first time, fear when the enemies attempt to kidnap her, etc.. Through the relationship with Elizabeth the human player can also discover his own character's personality and backstory, and infuses believability to the world. Unlike most other games featuring a companion, Elizabeth does not engage directly in fights, instead aiding the player by throwing ammo and health, for instance.

Figure 1.3: Care to dance? (Image from BioShock Infinite, Irrational Games.)

[13]BioShock Infinite. 2013, Irrational Games, 2K Games. `http://www.bioshockinfinite.com`

1.4 Our proposal

Drawing inspiration from the fundamental principles of traditional animation[2] that infuse believability in fictional characters, we believe that, by separating an action in two stages - anticipation, execution and execution - we can improve the cooperation and coordination between agents and the human player in a believable way. To achieve this goal, in each action the agent should first express his intent (anticipation stage), then execute the action (execution stage). As a result, the human player will be aware of the agent's intentions, minimizing frustration and providing efficient coordination while keeping the player immersed in the experience.

1.4.1 Contributions

With this work we aim to apply the anticipation principle of traditional animation to interactive characters in video-games, and study how it can increase the believability perception and also allow for new possibilities in interaction and story-telling. We explore different state of the art approaches both in video-games and in academia and how they will in some way influence own approach. We present a model which can be applied to an agent that features our approach. Our approach also features a simple mental model that is influenced by the agents perception of external events in the environment, particularly by perceiving how other agents react to its declaration of intent (through the anticipation module). Through this mental model we aim to further explore the possibilities of the anticipation approach, and also increase the perception of personality, and thus believability, in the artificial character. We implement our model in a multiplayer soccer-like game called Soccer Pucks, which previously lacked any kind of artificial intelligence (AI). In order to validate our work, participants viewed four videos featuring four different approaches: An approach with featuring both the anticipation module and the common reactive module commonly used by agents in video-games, an approach featuring only the reactive module, another approach featuring neither the anticipation module nor the reactive module and, lastly, a video featuring agents without the anticipation and reactive module but with random animations, so we can rule out any bias regarding animations. The evaluation consisted on the ranking of believability dimensions which we present in section 2.6.2 and 4.4.2, and the ordering for each of the four videos by perceived believability.

Chapter 2

Related Work

In this chapter, we will present works that will serve as groundwork on which our approach will be built upon. We start out by mentioning the principles of traditional animation which served as inspiration in our approach. We mention how these principles improve believability in animation and how we can use these concepts and apply them to guide the behaviour of synthetic agents and, just like in traditional animation, improve the believability and improve predictability of agents actions in a cooperative game. We then talk about the strong relation between emotions and believability and how our agents will express emotions. Next, we briefly mention the BDI architecture as it will be implemented in our agents, and also a paper regarding efficient decision making for agents in a simulated 3D environment.

We will then proceed to talk about believability measuring and validation. We'll go through a method used to evaluate the believability of agents in virtual environments in which the analysts relate the behaviours of the agents with the appropriate items in a table called Game Agent Matrix, and classify them as having positive or negative influence in believability in order to identify the weaker points in the behaviour that need improvement, and we end up this section describing an approach for user testing that uses a set of metrics to measure perceived believability.

2.1 Principles of Traditional Animation

According to John Lasseter[2] the understanding of fundamental principles of traditional animation is essential to produce great animation, both traditional animation or computer animation. These principles were first introduced by the Disney animators Frank Thomas and Ollie Johnston in their book The Illusion of Life: Disney Animation[6], and are based on the early standardized practices followed by the animators working at Disney. These principles allowed for more believable and lifelike animation.

- ***Timing*** reflects the speed of the action. All animated objects should have coherent timing according to their weight, inertia and motion speed, otherwise the idea won't come across to the audience. A large boulder needs a stronger force and more time to initiate its motion than a lighter object such as a marble. The illusion of physics are conveyed through this principle. Timing is applied not only to the action itself, but also to the preparation of the action and to the "post action" which, in turn, are two of the animation principles - ***Anticipation*** and ***Follow Through***, respectively.

- ***Anticipation*** is the preparation for the action. Anticipation serves as a declaration of intent. It "warns" the audience for the upcoming action, having it expect it before it actually occurs. When an animated character is about to throw a stone, it usually rotates his hip, leans back and draws

his arm backward before actually throwing the stone. Without anticipation the action would seem unnatural. Anticipation also leads the audience attention to certain artifacts, so if a character stares happy at a particular item, the audience will also focus on that item because there is an expectation that the character will interact with it. Because our work is about improving the interaction and cooperation between synthetic and human players, Anticipation is of the utmost importance to our work, as it will be a helpful device for the human player to decipher the intents of the synthetic teammates.

Figure 2.1: There is an important buildup before actually throwing the ball

- ***Staging*** is the presentation of an action, character or an idea, in a way that is clear to the audience. In order for that to happen, the audience's attention must be led to the action at the right time, otherwise the idea will be missed. Also, the audience shouldn't be overwhelmed with many ideas happening at once or they will be confused and won't know where to look. So only one idea should be presented at a time. One technique used to lead the audience attention is to make the object of interest to contrast with the rest of the objects in the scene, so in a frenetic scene the still object will have the audience attention, and in a still scene the moving object will have the attention, the same result is achieved using dark and clear colors. Good staging can also be accomplished by a proper camera angle or lightning. Because staging is intimately related to both ***Timing*** and ***Anticipation***, it will also be very important to our work, as the actions and intentions of the surrounding characters must be clear for the player

- ***Follow Through and Overlapping Action*** are closely related techniques that can make the animation much more believable. The Follow Through is what happens after the action was executed, making it the last of the three stages of the animation process, with the first being Anticipation, and the second the action itself. Follow Through means that the animation doesn't come to a full stop when the action is finished. So, for example, after a pitcher throws a ball, his arm and torso will continue the motion due to inertia. It would definitely be stiff and awkward observing it otherwise. Overlapping Action, on the other hand, states that an action doesn't need the end in order for the next one to start. So a character may be walking and reaching for the doorknob at the same time - it shouldn't have to stop walking in order for its hand to reach the doorknob.

- ***Slow in and out*** refers to the acceleration and deceleration of the motion required to produce believable animation. It is achieved by having more frames near the extremes of the action, and fewer in the middle.

- ***Arcs*** states the path of an animation is described by an arch. There are certain cases, such as when an object is falling, where the path is described by a straight line, but even then, usually the object rotates. Arcs provide for smoother and more natural animation.
- ***Exaggeration*** prevents the animation from becoming dull and makes the character's emotions easier to come across to the audience. How much an animator should exaggerate is dependent on the style of animation and its level of realism.

In our work, we will draw direct inspiration from the notion that an action is divided in two stage: anticipation and execution, as in these principles of traditional animation. The remainder of the mentioned principles will also influence our work and are important to have in mind. For example, if an agent expresses its intent but such expression hasn't the correct staging, the player may overlook.

However, there are other principles which go beyond the scope of our work: **secondary action** which is an action that supports the main action, such as blinking while talking, **squash and stretch** which states that rigid bodies should deform to add a sense of flexibility and inertia, **straight ahead action and pose to pose action** which are two different approaches do hand drawn animation, and **appeal** which refers to the overall quality of the animation and the characters.

2.2 Emotions and believability

Taking inspiration from traditional animation to improve agent's believability is not something new. In his paper[4] *The Role of Emotion in Believable Agents*, Bates argues that artists, not scientists, have come closest to capture the qualities that are able to make a creature appear alive. One quality that is particularly important is the ability to express emotion, which, in traditional animation, according to Thomas and Johnston, is what gives Disney's animated characters the illusion of life[6]. Bates further argues that an emotionless character is merely a machine, and that the agent should express itself in a way that makes us believe that it has fears and desires, and that it cares about the world around it. In Eurico Doirado's creation DogMate[14] the dog companion communicates with the human player by expressing emotions such as anger, fear or joy.

In our approach, we aim to provide emotion to the characters using a reactive module which will later be described. The agent will express frustration if it missed the pass, or joy if it scored a goal, for example. Our goal is to convince the human spectator that it wants to achieve its goals and meet its expectations and is emotionally affected by events in the course of the game.

2.3 Cooperative agents

There has been progress as far as believability goes regarding cooperation with synthetic companions. Eurico Doirado investigated how believability could be enhanced by anticipating the human player behaviour[14]. He used an affective anticipatory mechanism called Emotivector[10] that made possible to infer, based on distance and velocity variations between the human player and the other entities (such as enemies, objectives...) surrounding him, his underlying intent. He implemented this model in a synthetic sidekick - a virtual dog named Rusty - that, with this information, was able to react accordingly and in a believable way based on the sensations it experienced, for example, it would express his worry if he predicted the player was going to engage an enemy if the player's character had low health. Conversely, if Rusty believed the human player was able to take down an enemy and he predicted confrontation (based on distance reduction between the human player and the synthetic enemy) he would get exited.

His reactions in the different scenarios would serve as an advice to the human player. The result of this study suggested that the framework can be used to successfully identify some of the player's intentions.

Jonathan Tremblay and Clark Verbrugge investigated the field of adaptive companions applied to first person shooter games genre[18]. They used *Behaviour Trees* to model a sidekick that cooperates with the player in a believable way, learning and adapting itself based on the player's experience, and shaping its own behaviour. They start by making a clear and important distinction between two kinds of companions: The **fully autonomous companions**, which are independent companions over whom the player has no direct control over. The authors use Skyrim as an example of a game which implements this kind of companion, which often breaks the suspension of disbelief by walking in front of the player in fights, engaging in combat when the player intends to sneak, etc. Ideally, the fully autonomous companion should help the player by using a matching or complementary approach to battle that would potentiate its strength and the player's, but open games often struggle to achieve this. And the **semi-autonomous companions**, which allow the player some degree of indirect control over the companions, such as in games where the player can give orders to his sidekicks (which usually they obey blindly), or select the companions stance such as agressive, or defensive, as in Dragon Age.

The model developed for the adaptive companion attempted maximized player experience by optimizing *game intensity*. Game intensity pacing is crucial to a good game experience[13], as excessively long periods of high or low intensity tend to respectively frustrate and bore players[3]. Using this notion, the model measures the current intensity of the game (mainly based on variation of player health), and select the optimal companion behaviour from a pool of three distinct options:

- ***Cautious:*** The companion will engage the enemy only if a fight is already going on. Otherwise it will not attack enemies on sight, trying to take cover, hiding in a position near the player's if an enemy is spotted.
- ***Support:*** The companion will engage enemies on sight, and chase them to their last know position. Otherwise it will closely follow the player.
- ***Aggressive:*** This behaviour is meant to reduce the game intensity. The companion will actively explore the area around the player in order to try to find enemies to engage.

Besides game intensity, other metrics were developed to measure the performance of the companion: The *personal space*, and *combat load ratio* metrics. The personal space metric is helpful at determining if the companion is so close to the player that gets in the way of his movement and fire and thus breaking the suspension of disbelief, and the combat load ratio, which determines who's fought more, the player or the companion.

They proceeded to develop a third-person shooter prototype in which the goal of the player was to collect blue boxes. There are several enemies traversing a pre-defined path that try to prevent the player from achieving his goal by attacking him, and his companion, if they are seen. The enemies will also chase them to their last known position if they run away. The companion will try to defend the player by helping him in combat. To test, the authors created three scenarios in the prototype and the role of the human player was filled by a basic AI several times, emulating different players with different skill. The results showed the adaptive companion to have a positive impact on game intensity levels, specially during intensity "spikes", hence, theoretically improving the game experience. The companion also spent less time in the player's line of sight and in his personal space displaying more believable cooperation. Unfortunately, there was no "human playtesting" as of the time this paper was released. It would have been enlightening to have player feedback of this very interesting approach.

2.4 Communication between and with agents

In order to create believable behaviour, the creator must strive for more than just believable cooperation. The way the agent expresses itself and communicates with others is equally important.

Loyall and Bates extended Hap, which is a behaviour based architecture, to include, besides text generation, agent attributes which are important to believability such as action, perception inference and emotion[7]. This approach resulted in agents capable of using these attributes to influence communication, which reflected the agent personality. In the article, the authors begin by identifying some challenges in creating believable communication. Some of these challenges, which will be relevant in our work, are related to the tight integration of actions and language, and actions as a complement to the language, such as facial expressions while talking. The authors also note that language generation does not red+uce responsiveness, that success or failure in communicating will result in emotion, and that perception and action occur as subgoals of language generation, such as when we yell at someone if we perceive are not paying attention to us. In our work, the agents will express themselves through gestures (See *Solution*, section 3), but these challenges will nonetheless be valid in our work.

In multiplayer games with other human players, specially in games where cooperating and coordination between players is crucial, the player can usually use natural language, either by typing messages or through speech, so communication is usually not an issue in this scenario. However, as Gorniak and Roy point out[9], this same level of cooperation and coordination may be equally needed in games that feature synthetic characters that team up, and, in this case, communicating in natural language is very hard due to noise and also the semantic and syntactic complexity, so cooperation is often achieved through less desirable point and click interfaces. Gorniak and Roy attempted to overcome this barrier by contextualizing speech with the action, i.e., depending on where the speaker is located, her surroundings and the timing of speech and other aspects, the speech input is disambiguated. While the speech recognizer achieves a 50% word error rate it was augmented to deliver possible alternatives from each word spoken which are then shown in order of decreasing probability. The parser will then consider each alternative. By identifying the speaker intention, the speech recognizer errors are not as important as they would be otherwise, making this a robust approach in the subject.

In our personal perspective, we believe that, while communication is often crucial in multiplayer games, the optimal solution as far as believability goes, is having the characters themselves communicating with each other in an organic way instead. We believe it helps maintain the illusion, hence we are opting to communicate through character gestures in our approach.

2.5 BDI architecture

A Belief-Desire-Intention[5] agent architecture is a widely used approach to model rational agents and follows the Bratman's model of human practical reasoning with the same name[1]. A BDI architecture implement beliefs, desires and intentions in its agents. The beliefs represent the agent's knowledge gathered about the world as well as information about its own internal state, the desires are a backlog of goals, and intentions are the desires which the agent committed. The agent will aim to achieve its intentions through a plan.

The basic steps[11] of the execution of a generic BDI algorithm are:

1. An event is selected, either externally from the environment or generated internally by the agent

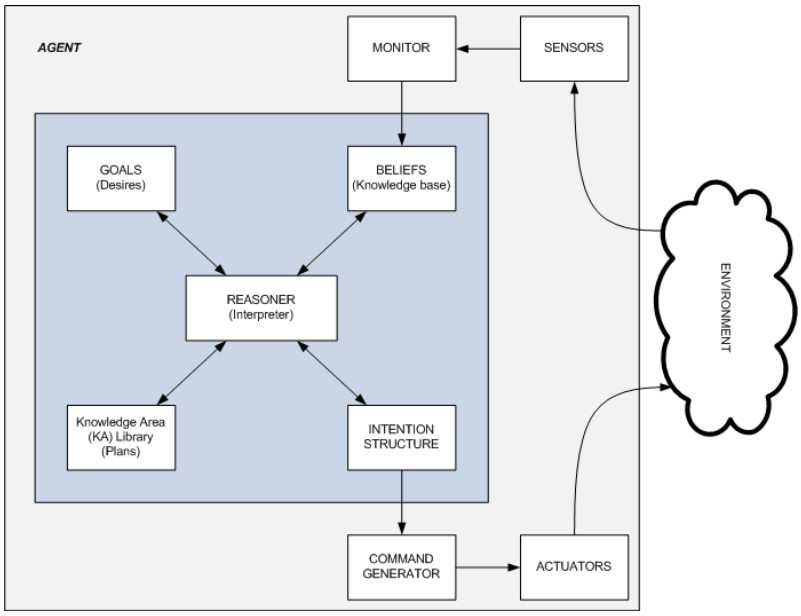


Figure 2.2: The Procedural Reasoning System (PRS)

2. Based on the information provided by the event, the agent will update its beliefs, goals and intentions.

3. A set of plans will be generated which, according to the agent's beliefs, are capable of tackling the selected event.

4. One of the generated plans will be either added to the list of intentions or update a current intention in the list.

5. The agent will execute the plan supporting the intention.

An implementation of the BDI architecture is the *Procedural Reasoning System* (PRS). The PRS (fig:2.2) was the first agent architecture to explicitly implement the BDI model[16]. The PRS agent has a library of pre-compiled plans, which are pre-set by the agent programmer.

2.5.1 Robocup

RoboCup is an annual tournament where teams of autonomous robots compete in a football match. Naturally, it draws the attention of many AI researchers that focus on more effective cooperation and decision making between robots. Since the game we will be implementing our model on - Soccer Pucks - draws inspiration from this competition, it is convenient to study how cooperation is handled between agents.

Although the decision making goes beyond the scope of our work, the paper *A simple method for decision making in RoboCup soccer simulation 3D environment*[12] introduces concepts that we believe to be very adequate for our work. They propose the introduction of several skills divided in two layers. In the first layer (basic skills) are the simpler actions, and in the second layer (high level skills) are the more complicated actions including combinations of basic skills. The decision making encompasses positioning, passes, attacking and defending, possession awareness and so on. Testing on RoboCup soccer 3D simulation environment revealed smooth cooperation and strategic coordination between the

team, with the agents executing the high-level skills with efficiency. The simplicity and scope of this approach led us to believe that would be the ideal guide to keep in mind when developing our agents.

2.5.1.1 Basic Skills

- *A(drive x y z)*: applies the force vector (x y z) to the center of the agent to move it.
- *A(kick alpha f)*: agent applies a force f to the ball with the angle alpha to it.
- *A(pantilt angle1 angle2)*: Changes the pan and tilt angles (angle1 and angle2 respectively) of the viewing direction of an agent. In Soccer Pucks, the agents do not have visual limitations, so this action does not apply.
- *A(say("say message here"))*: sends a message to all the players that are located in 50 meters from sender. In Soccer Pucks, the communication will be non verbal, through gestures, and visually available to every other agent (human and synthetic).
- *A(catch)*: is used only for goal keepers, to grab the ball if possible. In Soccer Pucks, this action not applicable, since there are not pre-determined goal keeper.

2.5.1.2 High level skills - Actions with the ball

- *Shoot*: As in Soccer Pucks, in this environment the agent, in order to kick the ball in the desired direction, must position himself correctly behind the ball, as he can only shoot in the direction ahead of himself.
- *Pass*: The agent passes the ball to a teammate. The authors define three types of pass: *secure pass*, in which the agent in possession is sure the ball will reach its destination, *normal pass*, which is riskier than secure pass, and *risky pass* which there is a high probability the ball will be intercepted. A risky pass is often use to create goal situations.
- *Dribble*: The agent may decide to proceed with the ball, until a passing or shooting opportunity presents itself.
- *Clear ball*: While defending, the agent clears the ball out danger. The direction of the clearance may be towards the opponent goal, out of play, or in any other direction. In Soccer Pucks, the ball can't go out of play due to forcefield walls that keep it in the court.

Drawing influence from this approach, we also made a similar division to the skills of the agents while implemting our model.

2.6 Measuring believability

2.6.1 The Game Agent Matrix.

Henrik Warpefelt wrote an interesting paper[19] in which he describes a method to evaluate the believability of agents in virtual environments. The methodology starts by the recording the interaction with the virtual environment. If it is a game, the player should play as he normally would, completing quests, interacting with NPCs, etc. Analysts would then proceed to locate, in the recorded footage, aspects

of the behaviour of the agent that impact believability, relate it to the appropriate item of a table called Game Agent Matrix, and evaluate it as either ”reinforcing” or ”lessening”.

The Game agent Matrix is represented in Table 2.1 on page 15. The leftmost column describes the maximum level of interaction the agent is capable of. *Act* and *React* relate to *simple reflex agents* respectively and *model-based reflex agents* described by Russel & Norvig[15]. Warpefelt describes an Acting agent as being *unaware of other entities in the world and only process the world as a world in which it can move about*, so, the acting agent perceives its environment as filled with obstacles that may need circumvention. Reacting agents are described as being capable of interaction with other agents, although it is limited to a responses stimuli. The reacting agent does not memorize previous interactions, and, as such, to the same stimuli they will repeat the response. The last type of agent in the GAM, is the *Interacting agent* is more socially complex agent which is capable to model the internal state of other agents and to become adapted to new social circumstances. It is able to avoid repetitive behaviour.

The columns of the GAM represent, from left to right, increasing complexity of social behaviour. Notice there can only be action and reaction in the first column, and in the following columns the increase in complexity of social does not make sense with *acting agents*. The definitions for the values in the GAM according to Warpefelt are found in Table 2.2 on page 16.

Warpefelt exemplified its use by analysing a vídeo[1] from the game *The Elder Scrolls: Skyrim*. It features an encounter between the player and an NPC near a lake. As the NPC character interacts with the player by asking a question, it gets attacked by a monster crab. Still, the NPC stands calmly waiting for the player response as he is attacked by the crab, shouting battle related remarks, such as ”This ends now!” but always standing still, looking at the player character waiting for it to respond. When finally the player does respond, the NPC says ”Well, until next time” and immediately dies from the damage he took from the crab. In this video, it is possible to identify in the GAM various problems regarding believability. The hunter seems unaware that he's being attacked by an enemy, failing in the items *Models of self, Models of Others, Adaptation* and *Lack of Awareness*. By not interrupting his conversation with the player to escape or fight the aggressor, he is also failing in *Interruptibility*. Warpefelt suggests various researchers engage in the analysis of the material, as this method is interpretative by nature. He also defends this method simplifies the correction of the behaviour by narrowing down the potential errors to the listed items from the GAM.

The Game Agent Matrix will be a helpful guideline in the course of our work, as believability is a crucial design goal of our model. Even though the game in which our model will be implemented is fundamentally different from Skyrim, the GAM is broad enough to suit our needs without requiring modification.

2.6.2 User Testing

In order to evaluate our approach, however, user validation is required in some form of quantifiable metrics. Gomes *et al* developed a set of metrics with the goal of measuring perceived believability[17]. These metrics, which the authors call believability dimensions, are the following:

- ***behaviour coherence:*** The audience will evaluate the behaviour of the agent regarding coherence, which is a key aspect of believability[8].
- ***change with experience:*** This dimension quantifies how the character is influenced by story events.

[1] `https://www.youtube.com/watch?v=v9m10FtMLew.com`

Table 2.1: The Game Agent Matrix (Adapted from: Evaluating the believability of agents in virtual worlds[19]

	Single Agent	Multiple Agents	Social Structural	Social Goals	Cultural Historical
Act	Goal Directed Route Following Uses language Uses tools	N/A	N/A	N/A	N/A
React	Adaptation Acquires Information Crisis response Interruptibility Awareness Models of self Rapid emotional response Navigation	Learns from others Models of others Face to face	Class difference Mob action Social ranking	Disillusionment	Advertising Institutions Roles
Interact	N/A	Memory of previous interactions Group Making Social Interaction Turn taking	Coercion	Clan wars Cooperation Group conflict Patriotism Power struggles Team player	Etiquette Norm maintenance Sanctions

Table 2.2: Value definitions for the Game Agent Matrix

Value	**Definition**
Goal directed	Strives towards a goal in the long or short term.
Route following	Able to transport itself across open ground between two points in the world.
Uses language	Use of spoken or written language.
Uses tools	Use of implements in order to seemingly achieve some sort of goal, for example a sword or a hammer.
Adaptation	Able to adapt to changing social circumstances in the world at the given time.
Acquires information	Observes the world and seemingly gathers information on which to act.
Crisis response	Reacts rapidly to a crisis, for example if it is being attacked or if there's a fire.
Interruptibility	Able to stop doing what it is currently doing when another task takes priority.
Awareness	Awareness of something in its immediate vicinity.
Models of self	Knowledge of its own existence as an entity, physical or mental.
Rapid emotional response	Emotional response to actions taken by others in the world, for example the killing of innocents.
Navigation	Able to dynamically adjust its route through the world in order to account for unexpected obstacles.
Learns from others	Learning from the actions of others, both by example and by direct teaching.
Models of others	Awareness of the existence of other agents, where they are and what they are doing.
Face to face	Turns towards the entity it is addressing.
Memory of previous interactions	Remembers previous interactions of note, both direct (conversations) and indirect (seeing each other at a significant event).
Group making	Dynamic creation of smaller groups.
Social interaction	Dynamic and meaningful interaction on a social level.
Turn taking	Awareness on a difference in social ranking, affecting things like credibility and who has the most social power.
Coercion	Forced actions
Disillusionment	Loss of belief in ideals.
Clan wars	Competition between groupings in the same area.
Cooperation	Ability do dynamically cooperate with other entities in order to achieve goals.
Group conflict	Conflict between groupings with different values and interests.
Patriotism	Strong dedication to parent group, for example the place of residence or clan.
Power struggles	Struggle for power between entities and groupings.
Team player	Being part of a team, and acting for the best of the team at the cost of itself.
Advertising	Advertises products and services.
Institutions	Roles and organizations with large amounts of formal or informal power and a historical connection, for example kings or universities.
Roles	Roles within society, for example police officers and farmers.
Etiquette	Observance of social rules and conventions.
Norm maintenance	Maintenance of norms and rules within society.
Sanctions	Application of sanctions towards entities and groupings that break the rules, law, or norms of society.

- ***awareness:*** The audience should perceive an agent to be aware of the world around it.
- ***behaviour understandability:*** The participant should be able to understand the character's behaviour. The agent must express itself in a way that its motivations and thoughts are clear to the spectator.
- ***personality:*** The agent should be perceived as an individual. Its behaviour should suggest personality traits that make it unique.
- ***emotional expressiveness:*** The agent should express its emotions.
- ***social:*** The social relationships between the agents must be clear to the audience.
- ***visual impact:*** The agent should draw the attention of the participant.
- ***predictability:*** A very predictable agent will harm believability just as much as a completely unpredictable agent, as it affects behaviour coherence[8], so either one of these extremes should be avoided.

The audience perception is assessed using Likert scales, using one scale per dimension. The templates for the phrases (except emotional expressiveness) to be rated by the subjects are:

- awareness: $<$ ***X*** $>$perceives the world around him/her.
- behaviour understandability: It is easy to understand what $<X>$is thinking about.
- personality: $<$ ***X*** $>$has a personality.
- visual impact: $<$ ***X*** $>$'s behaviour draws my attention.
- predictability: $<$ ***X*** $>$'s behaviour is predictable.
- behaviour coherence: $<$ ***X*** $>$'s behaviour is coherent.
- change with experience: $<$ ***X*** $>$'s behaviour changes according to experience.
- social: $<$ ***X*** $>$interacts socially with other characters.

For emotional expressiveness the participants are asked what emotions are displayed by the agent in specific moments, such as joyfulness or sadness. If participants frequently identified the same emotion the system was aiming to reproduce, this dimension would score higher. Conversely, if they interpreted a different emotion, the score would be lower.

The authors put forward the hypothesis that, apart from *predictability*, higher dimension values will result in a higher sense of believability.

Chapter 3

Solution

We are proposing a new, clearer approach to agent communication and cooperation. The core of our approach consists in dividing an action in two stages: **anticipation** and **execution**.

The anticipation stage, just as in traditional animation, serves the purpose of communicating the intent so every other agent and human player is expecting it and can prepare for it accordingly. The human player should be able to ”read” the intention of any other agent and to interact with it as well. After the anticipation stage is complete, the next step of the action will be its execution. In this stage, as the name implies, the action (such as passing the ball) will be executed.

The stages may be overlapped at any time. As such, an agent might make a pass and immediately after start a new anticipation stage, such as requesting the ball in an open area. The action may also be interrupted before the execution stage, such as when an agent expresses the intent to make a pass, but the opponent marks the teammate before it gets the chance to. The agents must be aware of each others current stage of the action, so it will be broadcast to every agent, otherwise they wouldn't be able to effectively cooperate. Conceptually, it will also be broadcast to the human player through gestures and ”body language”.

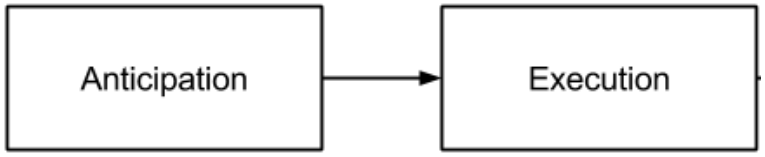


Figure 3.1: By dividing an action in two stages, we intend to expand the possibilities for believable interaction and cooperation.

3.1 Agent architecture

The *Decision Making* module will select an *Intention* according to both *Beliefs* and *Desires*, as expected in a BDI architecture. The intention will have associated a confidence value which will be generated according to the agents beliefs. When the action enters the anticipation stage, the agents in the environment may react in a way that will influence the confidence of the subject. If the confidence value goes below the confidence threshold, the agent will be frustrated, the action interrupted and the process starting all over again. Table 3.1 illustrates how positive and negative feedback can impact the confidence of an agent.

Expectation \ Feedback	Positive feedback	Negative feedback
Expects to score	Confidence += 30%	Confidence -= 15%
Does not expect to score	Confidence += 15%	Confidence -= 30%

Table 3.1: The impact feedback (given by the teammates) has in the confidence associated with an action

The percentage values in table 3.1, as the confidence threshold value, are dependent on the personality of the agent. Just as feedback impacts different people differently in the real world, it should impact different agents differently. With this approach, we aim to provide the possibility to easily develop agents with distinct personality types.

If the agent has a confidence value above the confidence threshold after all feedback is given, the action will enter the execution stage. The agent, as well as its teammates, will sense the outcome of the action and react accordingly. The outcome of the action can also influence the confidence associated with future intents. As such, if an agent is consistently having a bad game, it may be more reluctant to ignore negative feedback and thus more prone to execute actions that have its teammates consent.

The decision making module however, is beyond the scope of this work, and was emulated by a script. This script features both the actions and the confidence associated with the actions that each agent should perform sequentially. It may also set the desire of an agent. The script does not take care of the communication or synchronization between the characters, nor does it feed the agents the emotions it should display, as these items are the focus of our work and are accomplished dynamically.

Not every action is divided in two stages however, otherwise the observer would no doubt be overwhelmed and confused. We decided that there would be no anticipation stage for the simple action of moving from one place to another, or dribbling the ball from one place to another.

Figure 3.2 is an illustration of how the different modules interact with each other.

To summarize the role of the main modules of the agent architecture:

- ***Decision Making:*** Has the role of selecting an intent. To select the intent it considers the agent's desires and beliefs.
- ***Intention:*** The current intent selected by the Decision Making module. The intent has a confidence value associated with it.
- ***Sensors:*** The mechanism which will enable the agent to receive stimuli from the environment and its teammates.
- ***Expectation:*** The agent will have an expectation associated with the action at hand. It may believe he won't be able to score, for instance, or vice-versa. It is subject to the agent's base confidence value and confidence associated with the action.
- ***Affective Appraisal:*** The affective appraisal module will interpret the sensed stimuli and decide how it will influence the confidence of the current action if the agent is performing an action. It may raise the confidence or it may lower the confidence. The impact which will have on the confidence will be decided along with the agents expectation regarding the action.
- ***Emotional State:*** Is the mechanism which will decide the emotion to be displayed at a given time. It will be influence by the Affective Appraisal module.

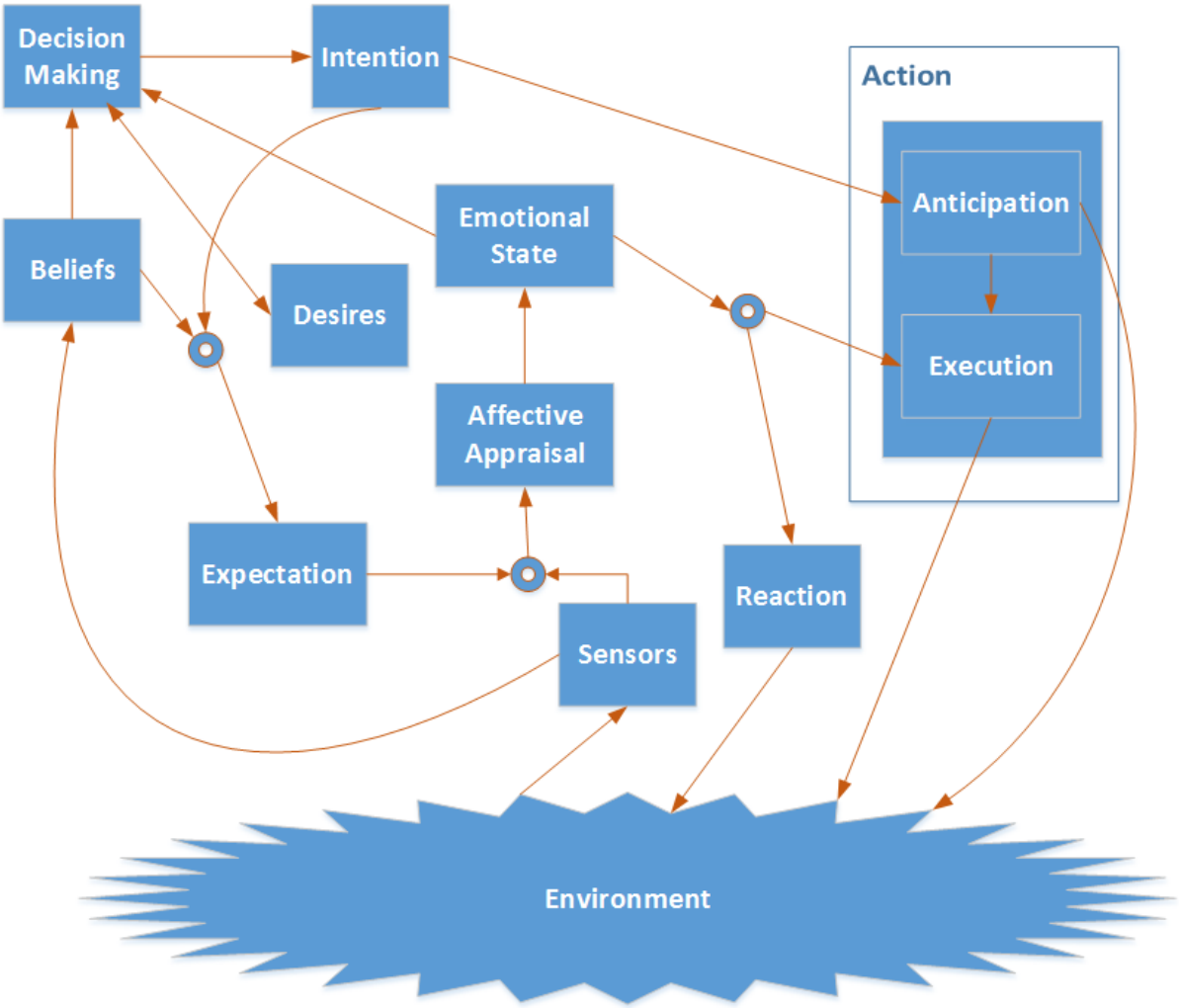


Figure 3.2: Agent architecture

- ***Action:*** The action is divided in two stages:
  - ***Anticipation:*** Before executing the action, the agent will broadcast its intention to the world.
  - ***Execution:*** The action is executed in this stage, if the action's confidence value is above the agent's base confidence value after the teammate's feedback.
- ***Reaction:*** The agent will express its emotions reactively depending on the events that occur in the environment. It will express reactively if a teammate missed an easy goal, or he does not agree with an intention of a teammate, for example.

3.1.1 Illustrative scenario

The combination of a mental model with the anticipation module leads us to potentially different outcomes in the same in similar interactions. In this section we will illustrate how the different modules communicate with each other in an example scenario. Consider figure 3.3.

Figure 3.3: This strip illustrates a scenario made possible with our approach

In figure 3.3, we have an agent, Tom, which is running with the ball and finds an opening to shoot at goal. His ***Expectation*** associated with the action indicates that he moderately believes he is going to score by shooting from that position. He broadcasts his intention to shoot at goal to his teammates. This broadcast is done in the ***Anticipation*** stage. His teammate, Sam, senses his teammates intention and, believing his in a good position himself, broadcasts his disagreement with Tom's decision to shoot. Sam uses the ***Reaction*** module to broadcast his disagreement. Tom then senses Sam's disagreement which is interpreted by his ***Affective Appraisal*** module and lowers his confidence associated with his action. Because Tom is an insecure agent, the confidence associated with the action gets lower than his confidence threshold. As such, the ***Emotional State*** dictates that he is frustrated and he relents by canceling his action before it enters the ***Execution*** stage and broadcasting his frustration.

In a similar scenario but without the anticipation module, this interaction would never be possible. Sam would never know Tom would shoot until after he had shot and thus, Tom would never have hesitated because he would not receive Sam's negative feedback until after he had shot. By broadcasting an intent before the execution of an action and introducing even a simple mental model a whole new level of possibilities arise. The human observer is finally able to tell a story within a non scripted action setpiece similar to what happens in a typical movie.

In our next section we will describe our implementation of this approach in a real time physics based soccer game *Soccer Pucks*.

3.2 Soccer Pucks

The model was implemented in a multiplayer sports video-game developed in *Unity 4*[1] called *Soccer Pucks*. *Soccer Pucks* is a physics based game where each player controls one character (unlike other sports games where the player controls the whole team) in a team of two or three elements with the objective of scoring more goals than the opponent. There are no pre-defined roles in *Soccer Pucks*, so each player must choose his positioning in the pitch based on his own preferences and also on his judgement of circumstances, dynamically, during the match.

Figure 3.4: Soccer Pucks

Because the ball isn't "glued" to the character in possession, such as in *Pro Evolution Soccer*[2], or *Fifa*[3] series, dribbling is tricky, so one-on-one's tend to be difficult. As a result, players are naturally encouraged to work as a team. In fact, cooperation is key in Soccer Pucks, making it a perfect set up to test our model.

We have also built a new character, more suitable for communication, that will use his hands to communicate and which we named Tom.

This character is loosely inspired by Rayman[4]. It has big hands seemingly unattached to the body, wearing white gloves. The hands will appear only when the agent is trying to communicate. The idea is to draw the human player's attention to the hands when required, and to make the underlying intention clear to the player.

Tom, as every character in *Soccer Pucks*, was modeled and animated using *Blender 2.7*[5]

[1] Unity 4, Unity Technologies. `https://unity3d.com/`

[2] Pro Evolution Soccer. Annually, 2001-present, BGEntertainment(2001-2004), Konami (2004-current), Konami. `https://pes.konami.com/`

[3] FIFA. Annually, 1993-present, EA Sports, Electronic Arts. `http://www.easports.com/fifa`

[4] `http://en.wikipedia.org/wiki/Rayman_(character)`

[5] Blender 2.7, Blender Foundation. `https://www.blender.org/`

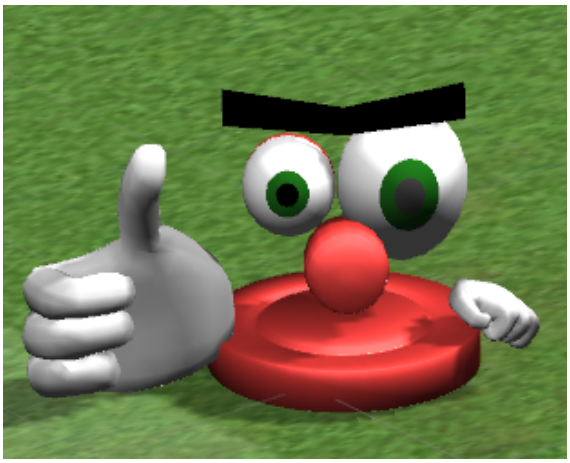


Figure 3.5: Meet Tom!

3.3 Agent's expressions

Tom is able to communicate with big hands that will show up when necessary. We developed four animations that communicate three different desires: Pointing, waving, reject pass, and thumbs up (see figure 3.6). These animations are exaggerations of real world gestures in a football match (figure 3.7).

Tom also expresses itself through its emotions. The reactive module in our architecture is able to deliver three distinct emotions: frustration, anger and joy (see figure 3.8). These emotions are used in a simple and straightforward way: If an agent misses a goal it shows frustration, when an agent asks for a pass but it is ignored and its partner misses the goal it will be angry, and when a goal scored it will display joy.

- **Agent's gestures**
  - ***Pointing:*** The agent uses its index finger to point to the area where it wants to shoot at. It is an animation used in the action's anticipation stage.
  - ***Waving:*** The agent distressfully waves its hands in the air, drawing attention to itself, displaying an intent to receive the ball. It may serve as negative feedback if the teammate had already expressed a different intent, such as shooting at goal.
  - ***Reject pass:*** The agent interprets the teammate's intent to pass the ball and rejects it, pointing to wherever he feels its teammate should place the ball at instead. This animation is similar to the *pointing* animation, except the agent swings his arm up and down in order to draw the teammates attention not to itself, but to wherever it is pointing. Because it contradicts the teammate's intent of passing the ball, it delivers a negative feedback.
  - ***Thumbs up:*** The agent acknowledges its teammate intent and agrees with it. It represents a positive feedback.
- **Agent's emotions**
  - ***Joy:*** Whenever a goal is scored Tom jumps in the with its fist in the air. We drew inspiration from common goal celebrations in football.
  - ***Frustration:*** This emotions is displayed when the agent misses a goal. A drop of sweat of exagerated proportions slowly falls from Tom's face. We drew inspiration from cartoons.

- ***Anger:*** Pressurized steam is leaked from both sides of the agent, where ears would have been. This animation is also a borrowed concept from many cartoons.

Although, as said before, the gestures and emotions drew influence from cartoons and real football matches, we needed to validate each one to make sure they were correctly identified. To do that, sent via e-mail short videos featuring a scene in which the agent expressed himself and displayed some emotion, and we asked the participants to interpret the emotion and intent. The evaluation was informal and we sent the videos to a group of less than ten participants. We were pleased to conclude that the participants correctly identified the agent's gestures and emotions in the videos.

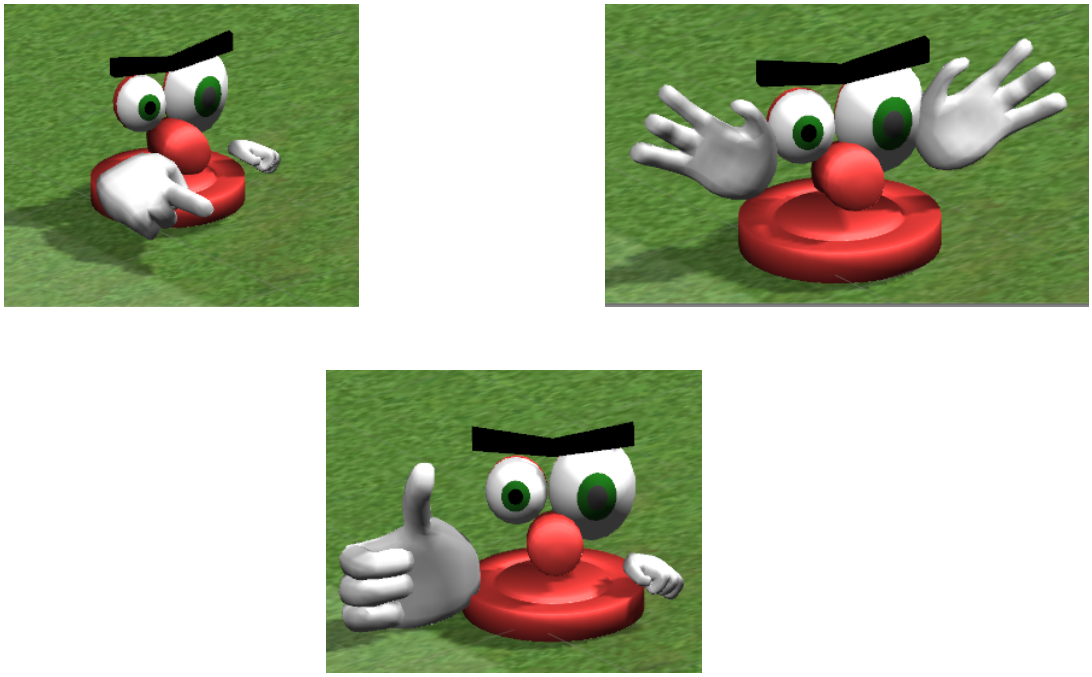


Figure 3.6: Tom's gestures: Pointing, waving and thumbs up

Figure 3.7: Tom's gestures were inspired by gestures from real players

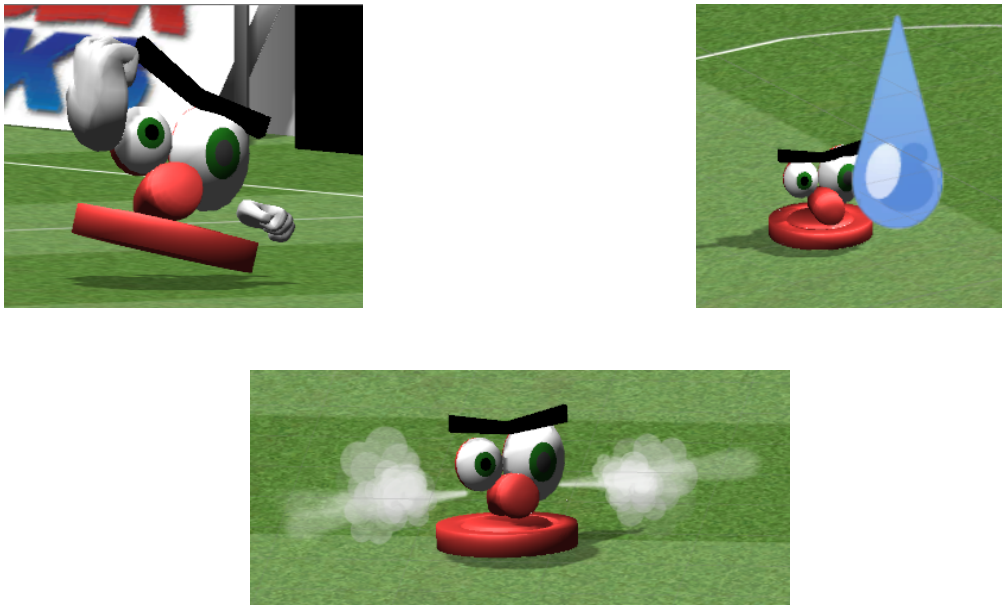


Figure 3.8: Tom's different emotions: Joy, frustration, and anger

3.4 Summary

In this section we presented our solution to clearer and believable agent communication and cooperation. We described the core of our approach to be the division of an action in two stages: The anticipation stage and the execution stage and we described our simple mental model which will, along with the anticipation module, enable new possibilities in character interaction.

Our mental model is fairly simple: The agents have a confidence threshold and a confidence value associated with every action. Through the anticipation stage they will broadcast their intentions and receive feedback, which will influence their confidence value associated with the action. If the confidence value drops below the confidence threshold the action is canceled and the agent is frustrated.

We also described our architecture and each of its main modules. We exemplified the way the modules interact by analysing an example hypothetical scenario in a soccer game in which an agent broadcasts his intention to score a goal, his colleague dissuades it from shooting and he relents, frustrated.

We proceeded to talk about the physics based sports video-game in which our approach will be implemented - *Soccer Pucks*. We presented Tom - the character that we created, and we presented the agent's gestures - Pointing, waving, reject pass, and thumbs up, and the agent's emotions - Joy, frustration and anger. We drew inspiration from cartoons and real life expressions in order animate Tom in a way that wouldn't confuse the observer. These expressions were informally validated by a group of participants.

Chapter 4

Evaluation

In this chapter we will describe our evaluation process which we used in order to validate our approach. We will start by describing the four scenarios we designed which portray distinct situations where agents interact. We proceed to describe our thought process regarding the questionnaire we asked users to fill and we end this chapters by presenting the results.

4.1 Experience

In order to have more control in the evaluation, we decided that the user should observe videos rather than watching a real-time demonstration. Due to the unpredictability of the physics, it was the only way we could assure every user would be watching the exact same scene.

We developed a questionnaire that would ask the participants questions regarding each one of the videos shown (see 4.2). The questionnaire was filled in 20 to 30 minutes. In order to avoid bias, we developed eight variants of the questionnaire with different question ordering. The participants were sent a link, mainly via e-mail, facebook, and the link would redirect the participants to a random version of the questionnaire. We opted for a Within Subjects Design as we wanted the participants to experience every video so the different perceptions across every video could be compared. The downside of the within subjects design is fatigue, and the memory of every video seen before, both of which may influence the answer to the questions. Because we used eight versions of the questionnaire with different video orderings, we were able to minimize the impact of these issues in the results.

4.2 Videos

We developed a scene with approximately fifteen seconds. In the scene there are two agents - two Toms - that are from the same team (Red). Their objective is to score a goal. There are no opponents in order to focus the user's attention in the interaction of the only two agents in the pitch. The spectators play no role other than to make the experience more visually appealing. In our following descriptions we will be referring to the agents as ”the top agent” and ”the bottom agent” to the agent which will always be in the left side of the pitch (hence nearer to the top of the screen) and to the agent which will always be at the right side of the pitch (bottom of the screen) respectively.

4.2.1 Scenario

In our scenario, the top agent dribles the ball to the left flank and initiates the anticipation stage of the action by showing its intent in shooting at goal (figure 4.1). The bottom agent, which intended to be passed the ball waves its arms in the air requesting the pass, to which the top agent relents (figure 4.2). The bottom agent receives the ball and scores the goal (figure 4.3 and figure 4.4).

Figure 4.1: The top agent displays an intends to shoot at goal

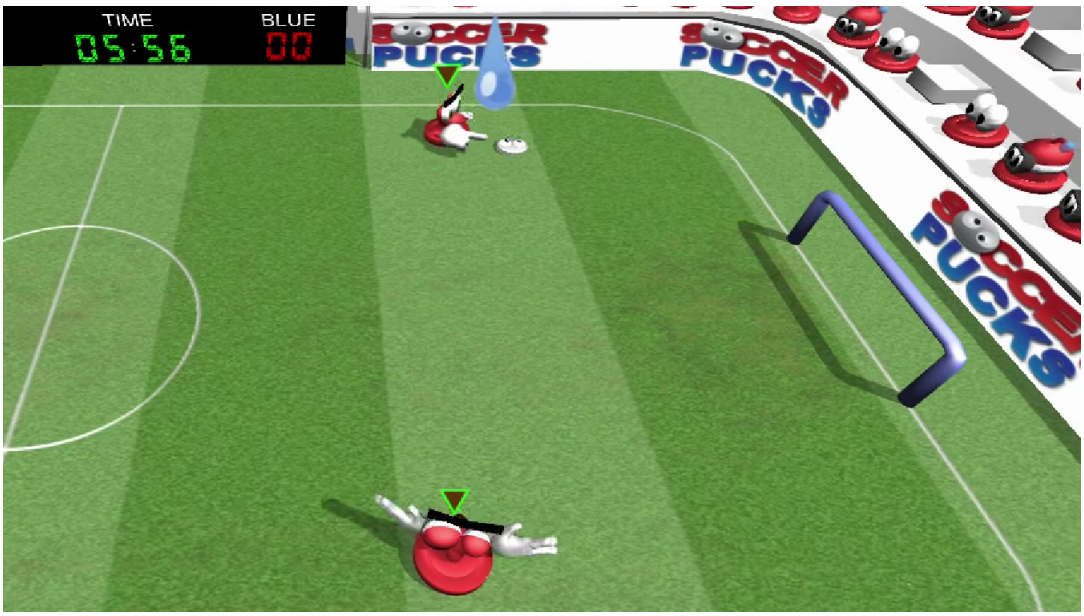


Figure 4.2: The bottom agent wants to receive the ball and as soon as he perceives the top player's intent, he waves his arms in the air in an attempt to persuade his teammate lowering his confidence in the current action. The top agent's confidence is now below his base confidence so he, frustrated, decides not to shoot at goal

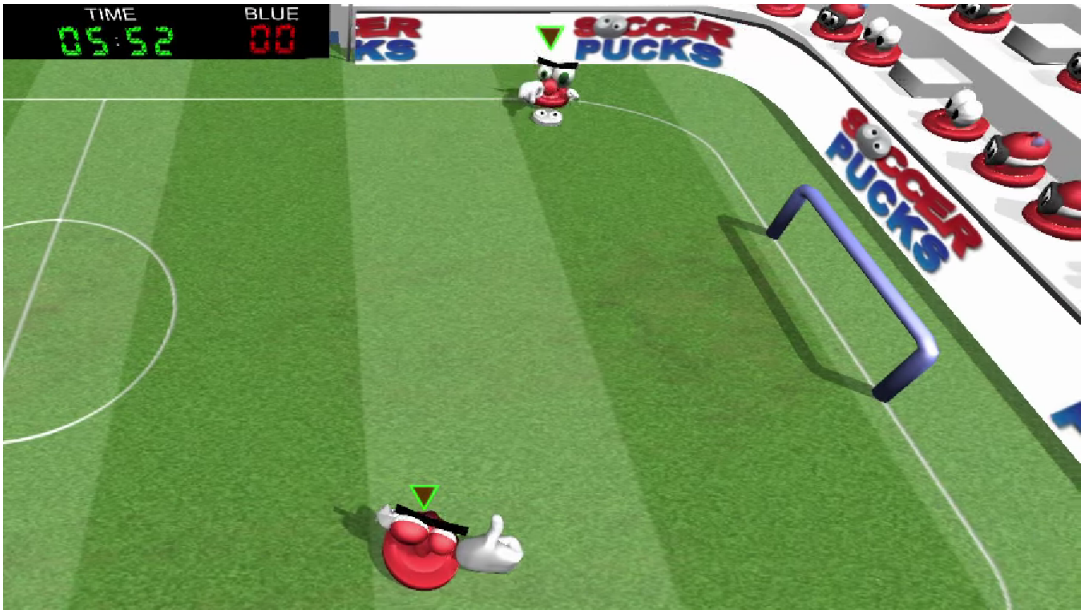


Figure 4.3: The top agent decides to pass the ball to its teammate, which readily agrees

Figure 4.4: The bottom agent displays an intent to shoot and, finding no opposition from his teammate, goes for the goal and scores

4.2.2 Additional videos

We have also used two aditional videos similar to the one that describe our scenario, but one is without the anticipation module and the other without both the anticipation module and the reactive emotion module. To dissipate the suspicion that the users may prefer the videos with both modules not because it is more believable but simply because it has more animations and thus is more appealing, we decided to introduce another video, similar in result as the others - The top agent passes to the bottom agent which scores - but with random animations that have nothing to do with the agents intentions.

By inhibiting the anticipation module (figure 4.5), the agents are solely able to communicate by reacting emotionally to external stimuli through the reactive module. Although, to make the illustration more clear, we did not exchange the arrows portraying the flux of information between the modules, it is important to note that the intention of the agent translates directly into the execution of the action and the anticipation no longer broadcasts the intention of the agent to the environment in this approach.

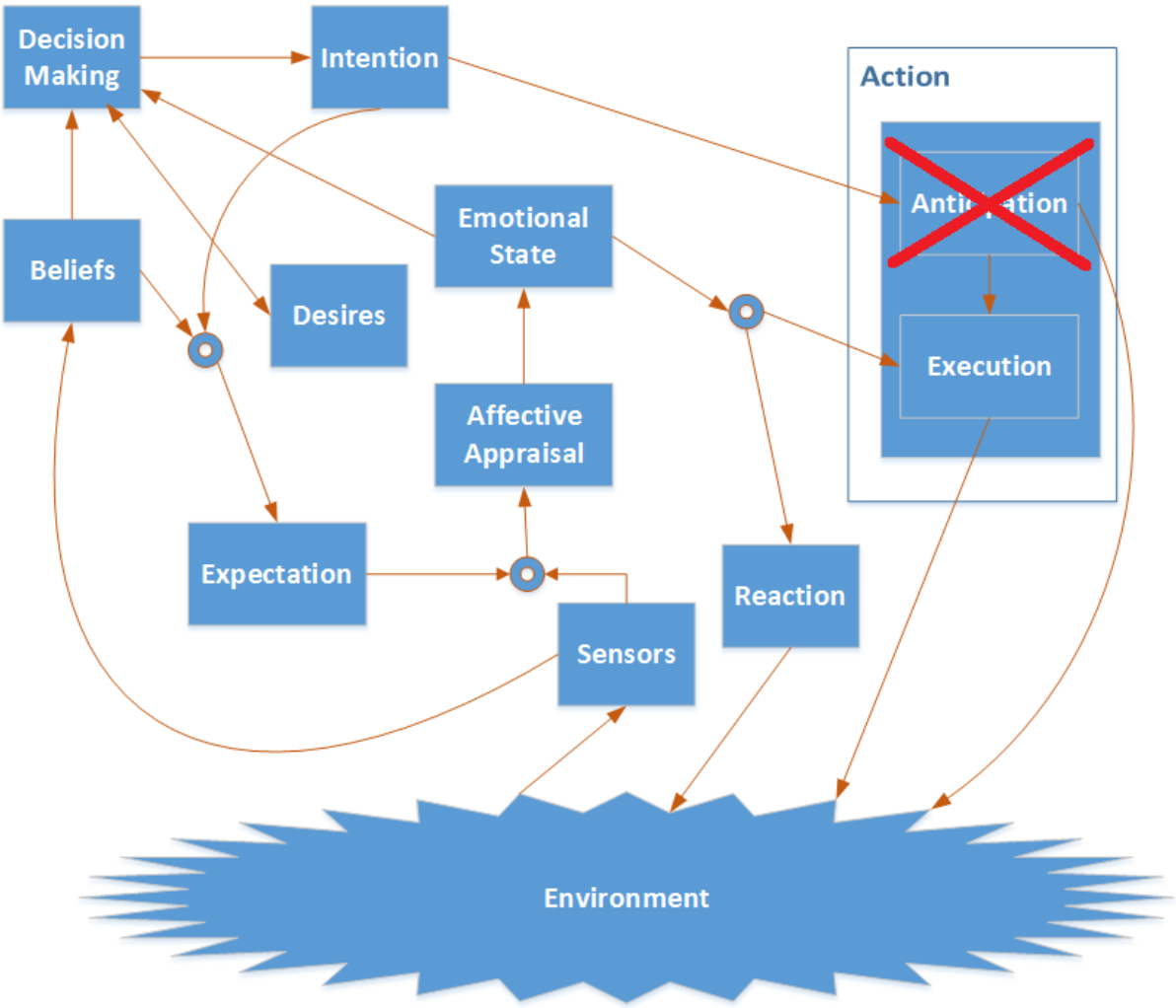


Figure 4.5: We included a video we in which the anticipation module was removed

Figure 4.6 shows both the anticipation module and the reaction module inhibited. By also inhibiting the reaction module, the agent no longer is able to communicate by gestures or display emotions.

It is important to note that our mental model looses much of its interest by inhibiting the anticipation module, since because there is no anticipation stage, the agent will no longer cancel its action before it

reaches the execution stage - Its teammates will not be able to give feedback because the intention was not broadcast to the environment to begin with!

For the sake of simplicity, we will be referring to the video with the anticipation module inhibited but with the reactive module active as the video featuring reactive agents. Although, to be precise, the agents are deliberative, we will call them reactive in the sense that, even though they lack anticipation, they are still able to react emotionally to external stimuli.

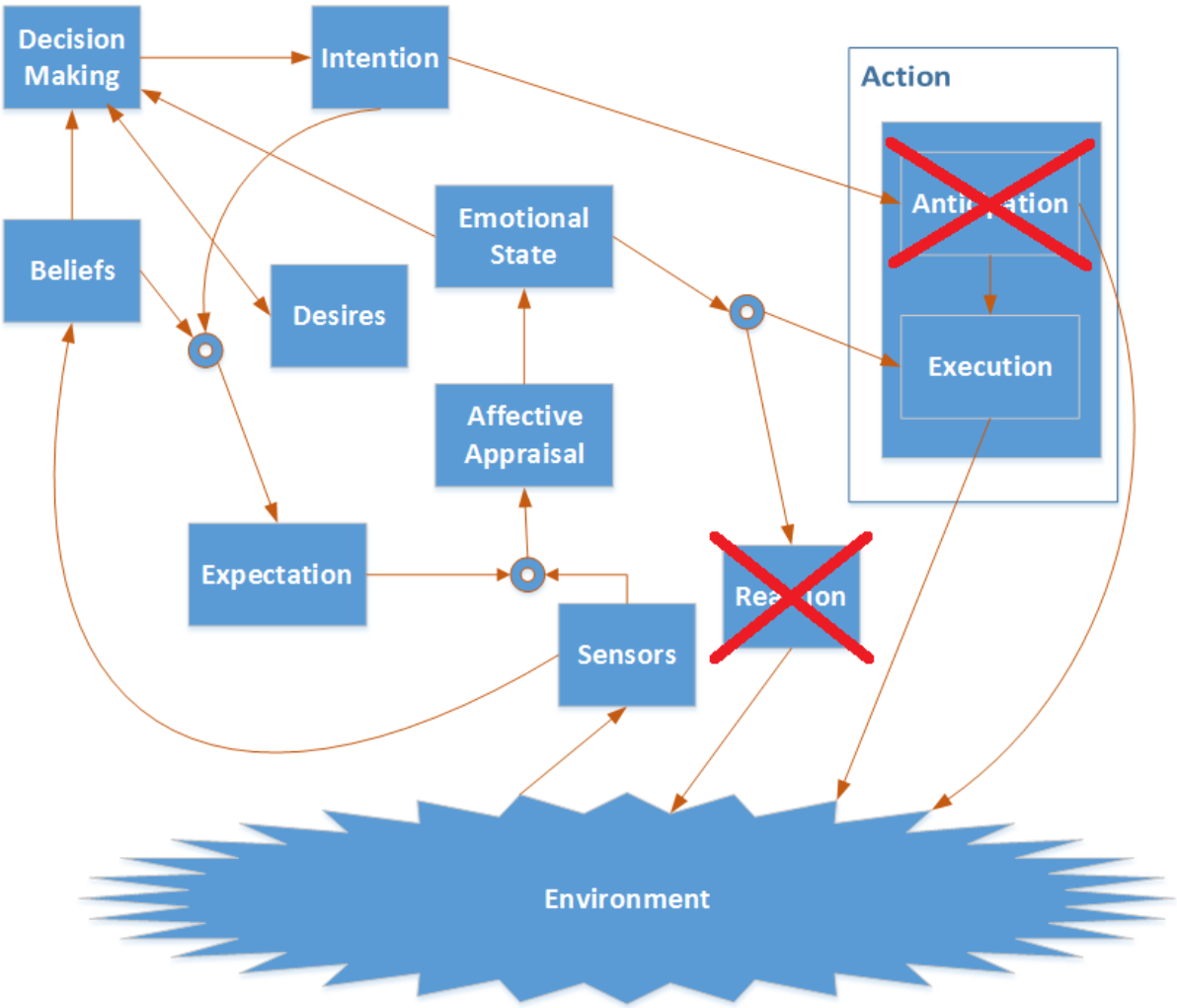


Figure 4.6: We also included a video featuring agents without both the anticipation module and the reactive module

Figure 4.7: We also included a video that displays random animations

4.3 Questionnaire

In our questionnaire we asked users to watch four videos, each with approximately fifteen second length. After each video, the users were asked for their agreement with the following statements:

- *The intentions of the artificial players are easy to understand.*
- *The artificial players are aware of their surroundings.*
- *It is easy to understand where each artificial player is focusing its attention on.*
- *The artificial players communicate with each other.*
- *The emotions of the artificial players are easy to understand.*
- *The artificial players clearly display their personality*

These statements are an adaptation of the work of Gomes et al[17] described in section 2.6.2. The audience perception was assessed using Likert scales that went to *1 - Strongly disagree*, to *5 - Strongly agree*.

We also decided to create a question to assess the user's interpretation of the agents intentions. In order to facilitate statistical treatment of the data collected, we decided to create two sets of multiple answer questions for each player, one for the top agent who passed the ball, and the other for the bottom agent who shot at goal. So, for the four videos we had:

- *Related to the top artificial player:*
  - *The top player passed the ball because that was the wish of the bottom player.*
  - *The top player passed the ball because that was its own wish.*
  - *I can not decide, the video is not clear enough.*
- *Related to the bottom artificial player:*

- *The bottom player intended to receive the ball.*
- *The bottom player did not intend to receive the ball.*
- *I can not decide, the video is not clear enough.*

Lastly the questionnaire featured a page with the same four videos, and asked which video portrayed the agents as "*life-like, believable creatures with interesting human-like qualities, and less like pre-programmed (ro)bots?*" The user was asked to order those four videos by order of preference. The videos were: the video with both the anticipation and reactive emotion module, without the anticipation module, without the anticipation and reacive emotion module, and the random video. After the ordering the user was asked, in open answer question, to briefly justify his choice and what would he suggest to improve his favourite approach.

4.4 Results

We will proceed to make an in-dept analysis of the video featuring the agents with both the reaction and anticipation module by comparing it to its three homologous variants: Without the anticipation module, without both the anticipation and the reactive module, and the one with random animations. In tables and in figures, these four approaches are respectively labeled *Anticipation, Reaction, None,* and *Random* for simplicity.

4.4.1 Participants

We collected 52 answers to our questionnaire. The distribution of age, gender, how frequently the participants play video-games, and specifically soccer video-games, are shown in figure 4.8

4.4.2 Believability measuring

The mean results for the six believability questions for each of the four videos, along with the respective standard deviations are show in figure 4.9.

The Shapiro Wilks test indicated that the data set for the six perceived believability measuring questions for each of the four videos are not modeled by a normal distribution therefore we will be using non parametric tests on our data. We then proceeded to apply the Friedman's Test in four exemplars of videos each representative of our model with anticipation and reaction, reaction only, without both modules, and a random animations videos to detect bias, in order to conclude whether participants ranked our videos differently.

In order to detect which videos are ranked differently, we proceed to use a Wilcoxon signed rank test, for each of the six believability questions.

The results for each dimensions are shown in the next following subsections respectively. The Wilcoxon signed rank test tables featuring the ranks, positive negative and ties, are in the section Appendix B.

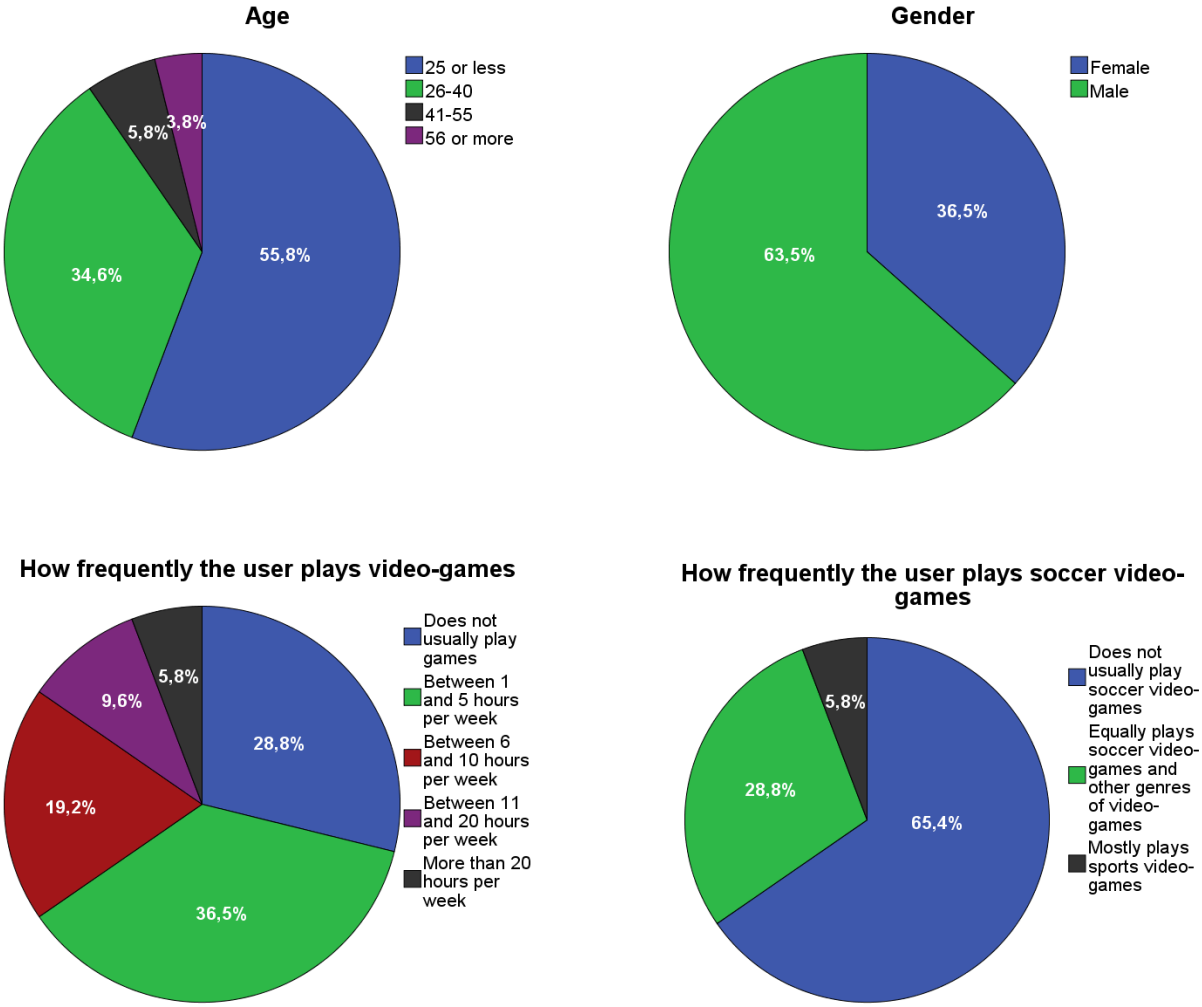


Figure 4.8: Participants information

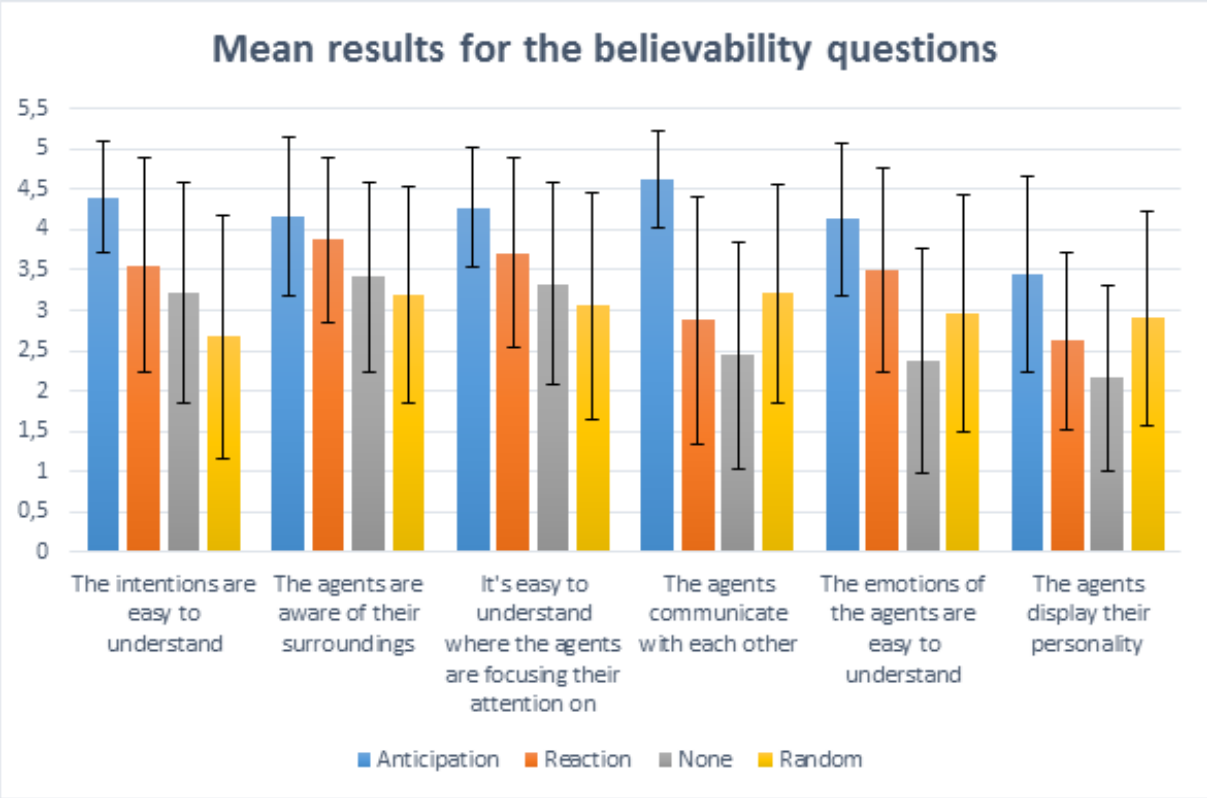


Figure 4.9: The mean results of the believability responses clustured by every video. The error bars represent the standard deviation

4.4.2.1 The intentions are easy to understand

- Friedman test

$\chi^2(3) = 54,404$, $p{-}value = 0,000$

Friedman test shows us that the dimension ”The intentions of the agents are easy to understand” is ranked differently for each video.

- Wilcoxon signed rank test

	Anticipation	Reaction	None
Reaction	Z = -4,151 p-$value$ = 0,000	-	-
None	Z = -5,062 p-$value$ = 0,000	Z = -2,074 p-$value$ = 0,038	-
Random	Z = -5,233 p-$value$ = 0,000	Z = -3,776 p-$value$ = 0,000	Z = -2,288 p-$value$ = 0,022

Table 4.1: Wilcoxon signed-rank test results for the dimension ”The intentions of the artificial players are easy to understand” for the four videos representative of each approach.

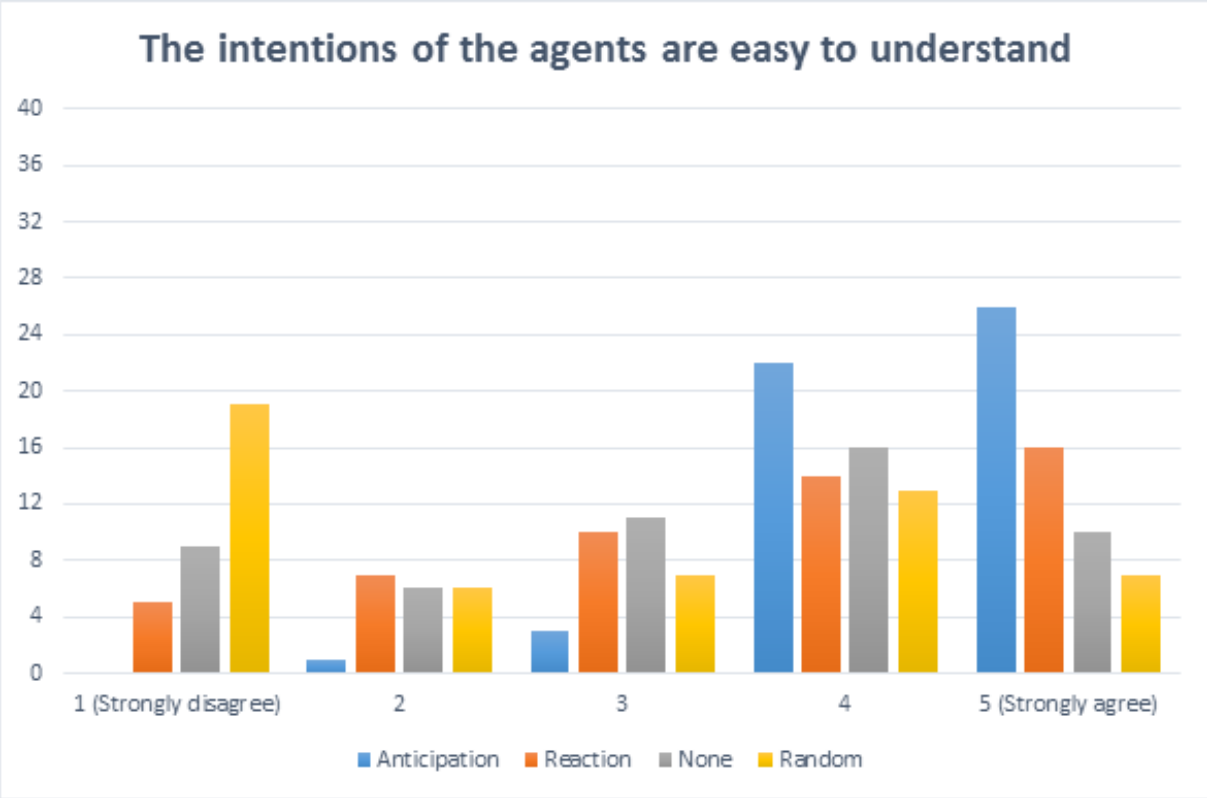


Figure 4.10: The frequency of the agreement rating of the dimension ”The intentions of the agents are easy to understand”

Table 4.1 shows us that, between the video with the anticipation module and the remaining videos, there is a statistical relevant difference in user perception of the agents intentions, with the preference clearly residing in the video with the anticipation module.

We can conclude that for the dimension ”The intentions of the artificial players are easy to understand”, the video with the anticipation is ranked higher when paired against its peers, followed by the video without the anticipation module but with the reactive module. The video with neither two modules active is ranked in third place and the video with random animations last.

4.4.2.2 The agents are aware of their surroundings

- Friedman test

  $\chi^2(3) = 24,258$, $p{-}value = 0,000$

Friedman test shows us that the dimension ”The agents are aware of their surroundings” is ranked differently for each video.

- Wilcoxon signed rank test

In table 4.2 we can conclude, that for a signficance of 0.05, there is not relevant statistical difference in terms of preference in the dimension ”The artificial players are aware of their surroundings” between the video with the anticipation module and the video with only the reaction module. Our approach is preferred, however, when compared against the video with neither module and the one with random animations.

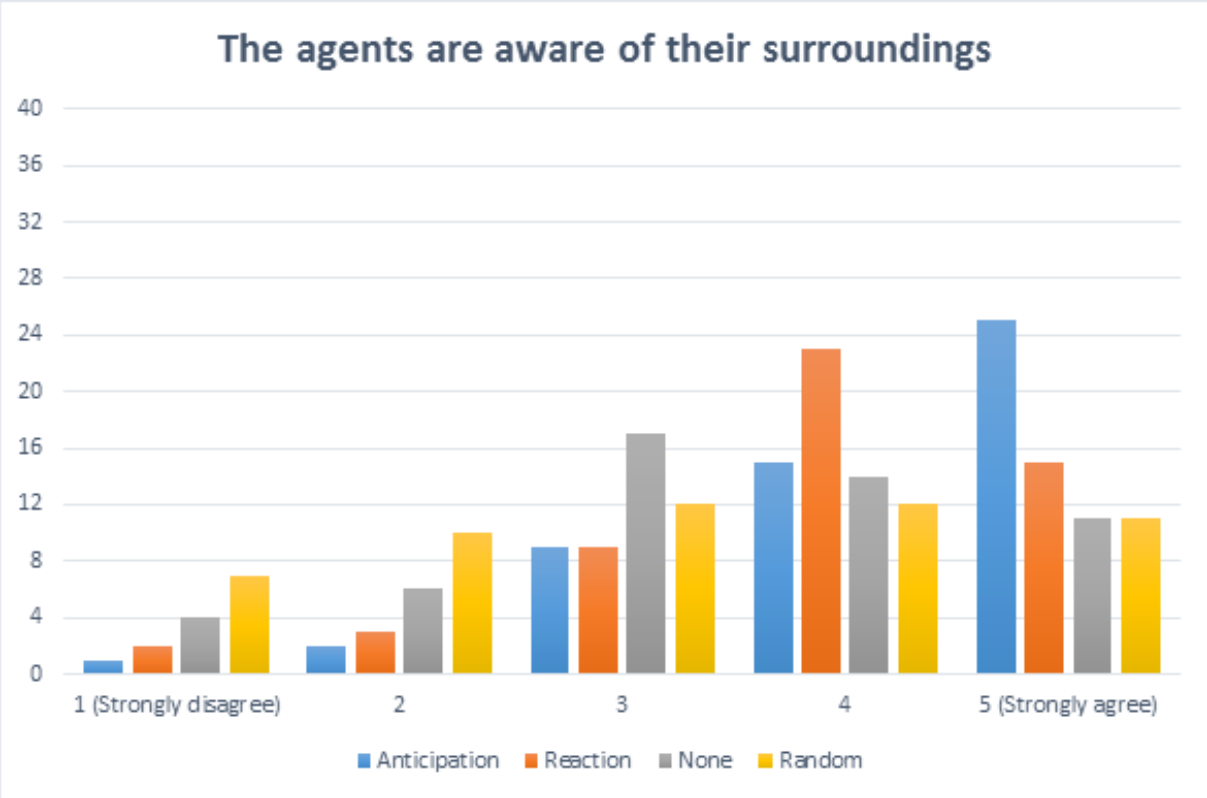


Figure 4.11: The frequency of the agreement rating of the dimension ”The agents are aware of their surroundings”

	Anticipation	Reaction	None
Reaction	Z = -1,638 p-$value$ = 0,101	-	-
None	Z = -3,197 p-$value$ = 0,001	Z = -3,198 p-$value$ = 0,001	-
Random	Z = -3,705 p-$value$ = 0,000	Z = -3,150 p-$value$ = 0,002	Z = -0,980 p-$value$ = 0,327

Table 4.2: Wilcoxon signed-rank test results for the dimension ”The artificial players are aware of their surroundings” for the four videos representative of each approach.

For the dimension ”The artificial players are aware of their surroundings”, the video with the anticipation shares the first place with the video with the video with reactive agents. The video with neither modules shares the last place with the video random animations last. This ordering leads us to believe that our approach does not impact the notion of environmental awareness.

4.4.2.3 It is easy to understand where the agents are focusing their attention on

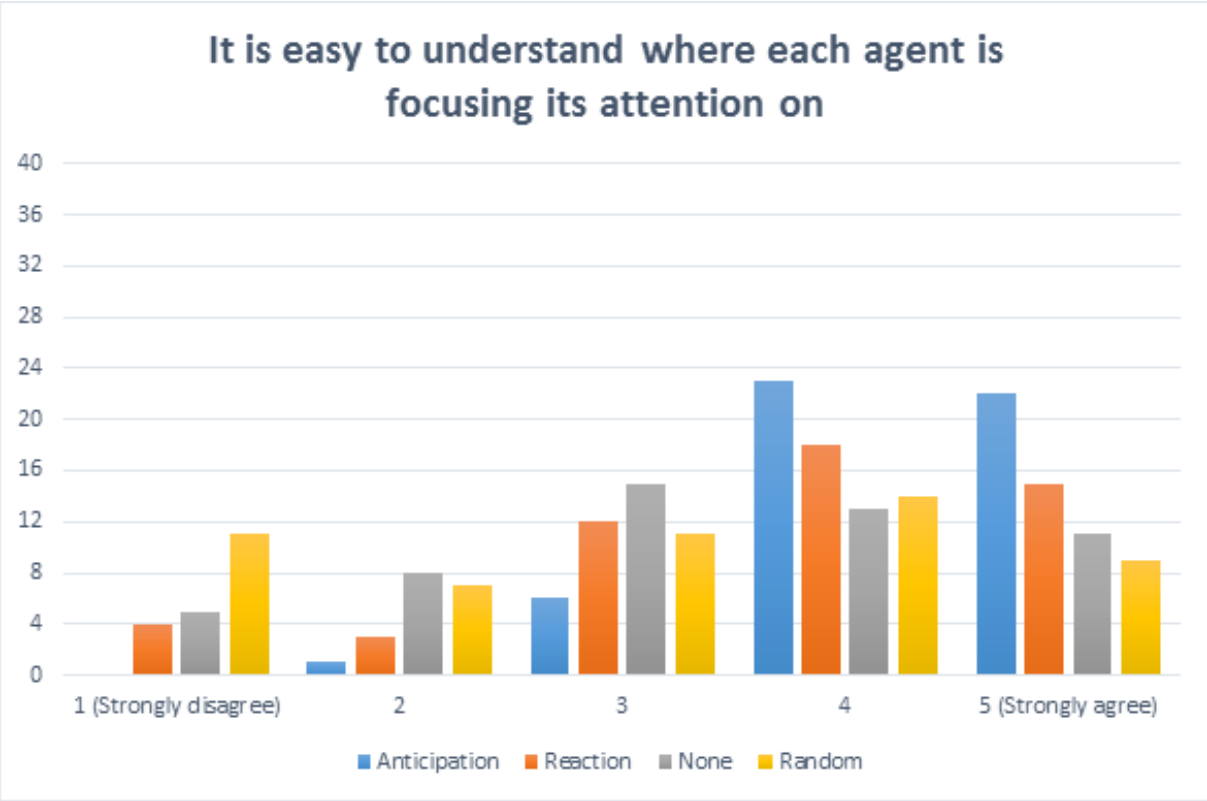


Figure 4.12: The frequency of the agreement rating of the dimension ”It’s easy to understand where the agents are focusing their attention on”

- Friedman test

  $\chi^2(3) = 32,236$, $p{-}value = 0,000$

Friedman test shows us that the dimension ”It is easy to understand where the agents are focusing their attention on” is ranked differently for each video.

- Wilcoxon signed rank test

Again, table 4.3 shows a clear preference on the video with the anticipation module against its peers in the dimension ”It is easy to understand where each artificial player is focusing its attention on”. Regarding the video with random animations against the video with neither module there is no statistical relevance for the preference of the participants for a significance of 0,05.

We can conclude that for the dimension ”It’s easy to understand where each artificial player is focusing its attention on”, the video with the anticipation is ranked higher than the remaining videos, followed by the video with reactive agents. The video with neither two modules active shares last place with the video with random animations last.

	Anticipation	Reaction	None
Reaction	Z = -2,857 p-$value$ = 0,004	-	-
None	Z = -4,359 p-$value$ = 0,000	Z = -2,515 p-$value$ = 0,012	-
Random	Z = -4,229 p-$value$ = 0,000	Z = -3,099 p-$value$ = 0,002	Z = -1,294 p-$value$ = 0,196

Table 4.3: Wilcoxon signed-rank test results for the dimension ”It is easy to understand where each artificial player is focusing its attention on” for the four videos representative of each approach.

4.4.2.4 The agents communicate with each other

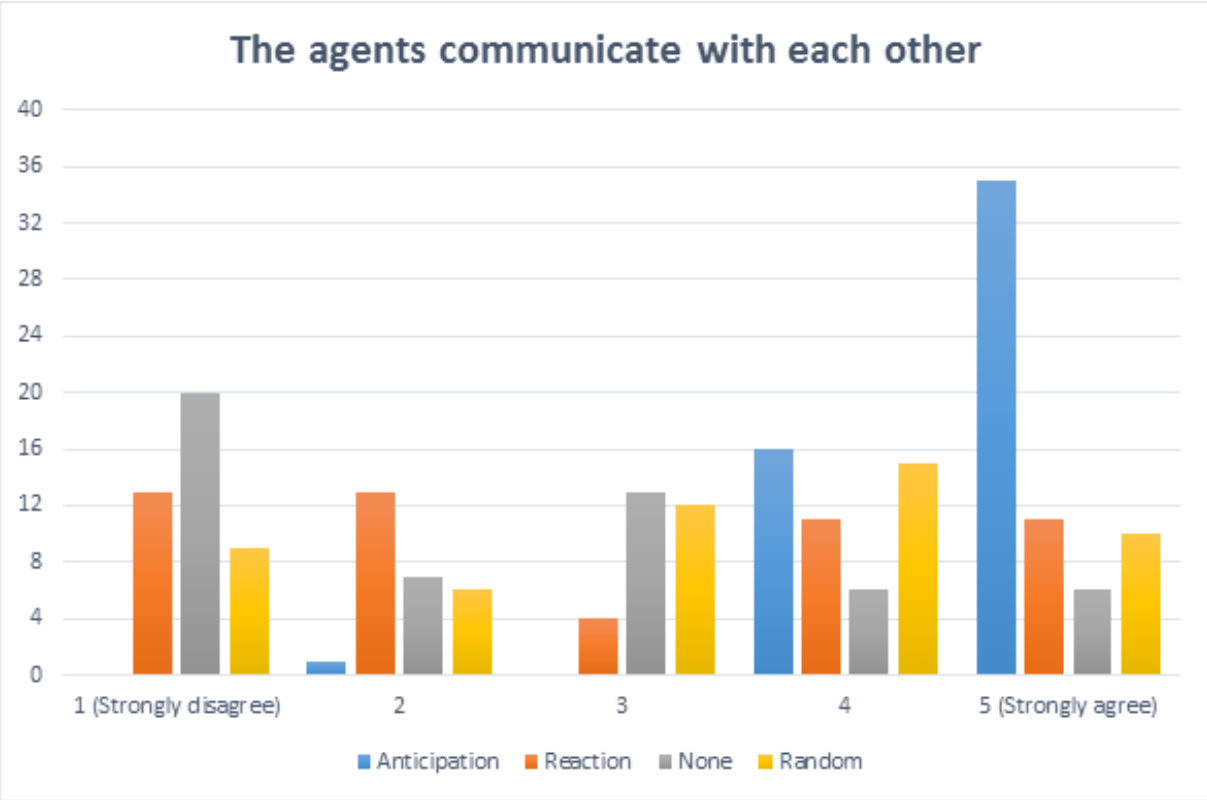


Figure 4.13: The frequency of the agreement rating of the dimension ”The agents communicate with each other”

- Friedman test

  $\chi^2(3) = 64,650$, $p{-}value = 0,000$

Friedman test shows us that the dimension ”The agents communicate with each other” is ranked differently for each video.

- Wilcoxon signed rank test

	Anticipation	Reaction	None
Reaction	Z = -5,371 p-$value$ = 0,000	-	-
None	Z = -5,769 p-$value$ = 0,000	Z = -2,926 p-$value$ = 0,003	-
Random	Z = -4,935 p-$value$ = 0,000	Z = -1,238 p-$value$ = 0,216	Z = -3,077 p-$value$ = 0,002

Table 4.4: Wilcoxon signed-rank test results for the dimension ”The artificial players communicate with each other” for the four videos representative of each approach.

As for the dimension ”The artificial players communicate with each other”, table 4.4 shows yet again a clear preference for the video with the antipation module. The participants did not make a statistically significant distinction between the video with random animations and with neither modules.

We can conclude that for the dimension ”The artificial players communicate with each other”, the video with the anticipation module is ranked higher than the remaining videos. Both the videos with reactive agents and the video with random animations are tied in second place. The video with neither anticipation or reaction is last.

Curiously, the video with reactive agents does not feature agents communicating through gestures, only emotions which result from the outcome of the actions, which may be interpreted as a way of communicating. In the video with random animations however, the agents do gesticulate in a random fashion. This may explain the similar rank of both approaches: one was penalized for lacking gestures, the other was penalized for having nonsensical gestures and emotions.

4.4.2.5 The emotions of the agents are easy to understand

- Friedman test

  $\chi^2(3) = 53,889$, $p{-}value = 0,000$

Friedman test shows us that the dimension ”The emotions of the agents are easy to understand” is ranked differently for each video.

- Wilcoxon signed rank test

Regarding the dimension ”The emotions of the artificial players are easy to understand.”, table 4.4 shows us the users felt the artificial players displayed their emotions more clearly in the video with random animations (we remind that these animations also include emotions) than in the video with neither module, which is understandable. The participants did not feel, however, that there was a difference between the video with random animations and the video with only the reactive module for this particular dimension give a significance of 0.05. Regardless, the video with anticipation is the best ranked video also in this dimension.

For the dimension ”The emotions of the artificial players are easy to understand” we can conclude that the video with the anticipation module is ranked higher than the remaining videos. Again, both the videos with reactive agents and the video with random animations are tied in second place. The video with neither anticipation or reaction is once again last. The tie between the video featuring reactive

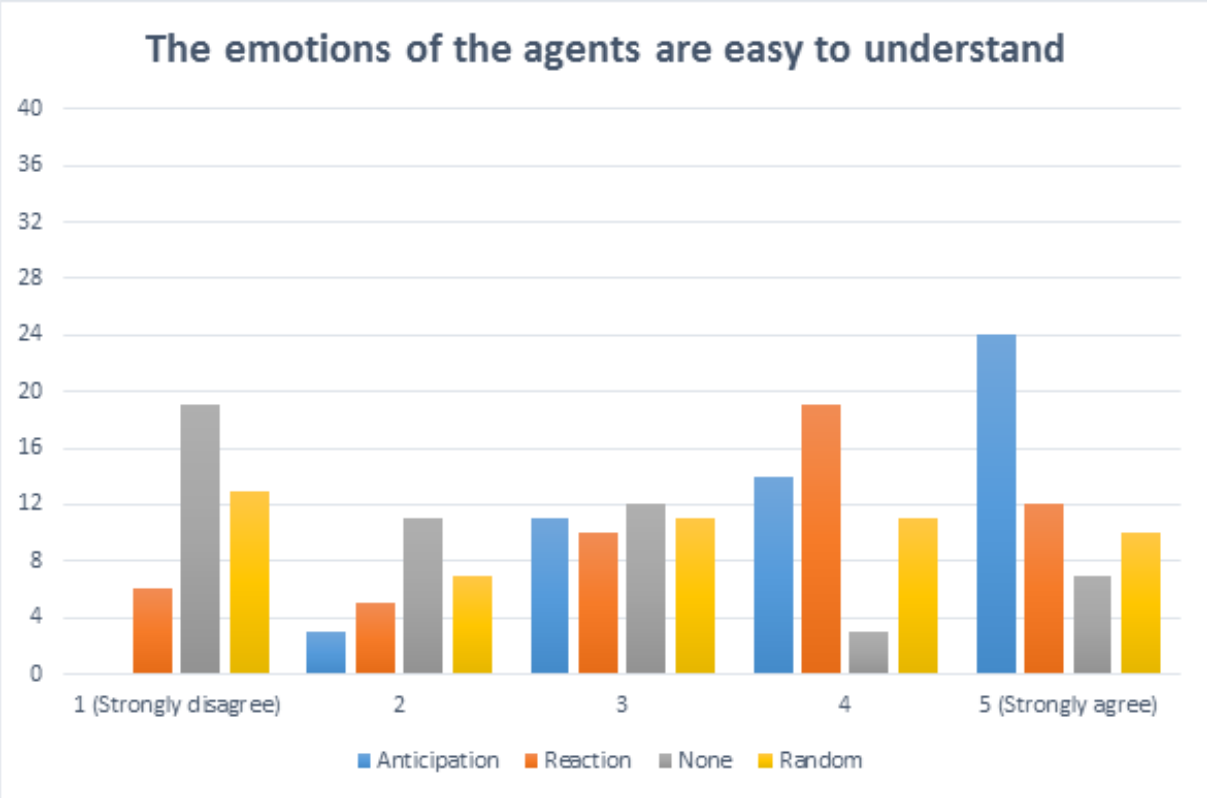


Figure 4.14: The frequency of the agreement rating of the dimension ”The emotions of the agents are easy to understand”

	Anticipation	Reaction	None
Reaction	Z = -3,314 p-$value$ = 0,001	-	-
None	Z = -5,414 p-$value$ = 0,000	Z = -4,632 p-$value$ = 0,000	-
Random	Z = -3,908 p-$value$ = 0,000	Z = -1,827 p-$value$ = 0,068	Z = -2,080 p-$value$ = 0,038

Table 4.5: Wilcoxon signed-rank test results for the dimension ”The emotions of the artificial players are easy to understand” for the four videos representative of each approach.

agents and the video featuring random animations was somehow to be expected, sense the agents in both videos display their emotions, even though on the latter they happen on random occasions.

4.4.2.6 The agents clearly display their personality

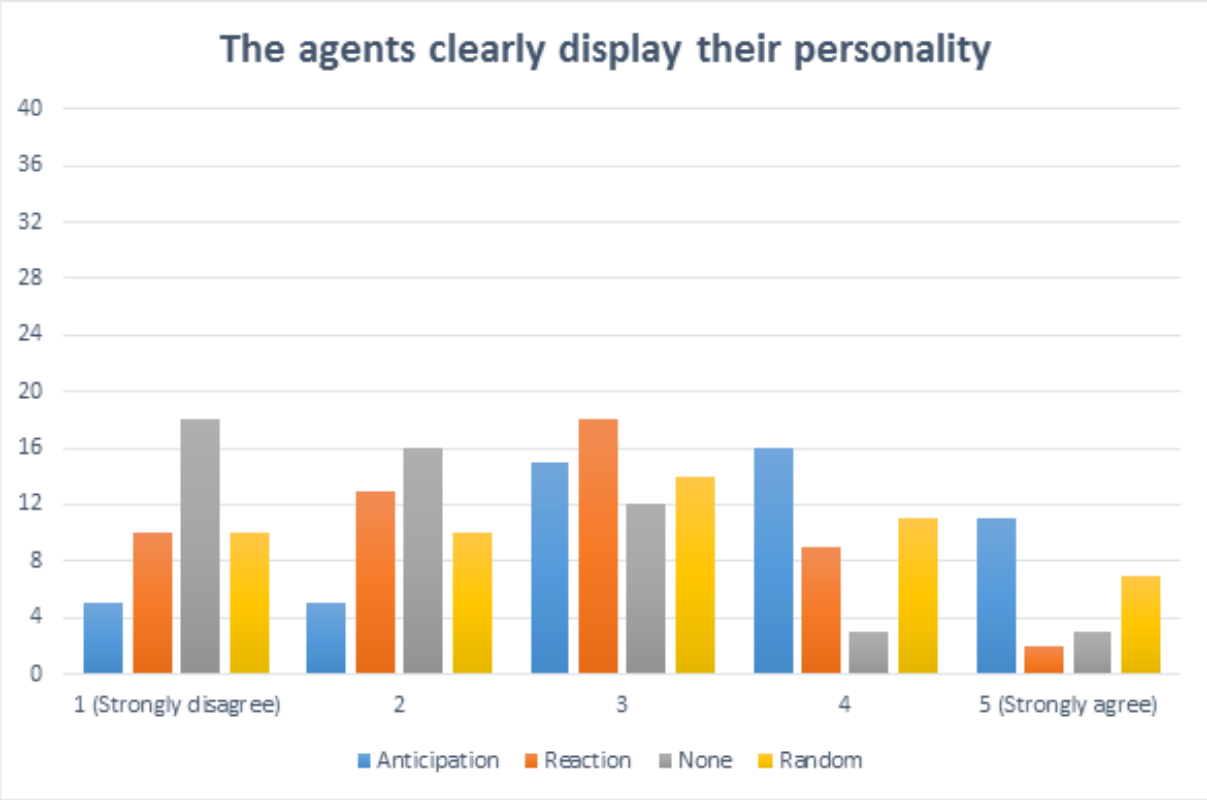


Figure 4.15: The frequency of the agreement rating of the dimension ”The agents display their personality”

- Friedman test

  $\chi^2(3) = 38,214$, $p{-}value = 0,000$

Friedman test shows us that the dimension ”The agents display their personality” is ranked differently for each video.

- Wilcoxon signed rank test

	Anticipation	Reaction	None
Reaction	Z = -3,998 p-$value$ = 0,000	-	-
None	Z = -4,735 p-$value$ = 0,000	Z = -3,160 p-$value$ = 0,002	-
Random	Z = -2,431 p-$value$ = 0,015	Z = -1,628 p-$value$ = 0,103	Z = -3,174 p-$value$ = 0,002

Table 4.6: Wilcoxon signed-rank test results for the dimension ”The artificial players clearly display their personality” for the four videos representative of each approach.

Table 4.6 shows us that, for the dimension ”The artificial players clearly display their personality”, the participants did not distinguish the video with random animations from the video with only the reactive module, for a significance of 0,05. As expected, the video with anticipation, is the most preferred video for this dimension.

For the dimension ”The artificial players clearly display their personality” we can conclude that the video with the anticipation module is yet again ranked higher than the remaining videos. Similar to the previous dimensions, both the videos with reactive agents and the video with random animations are tied in second place. The video with neither anticipation or reaction is once again last. We believe the fact that the video with random animations did portray agents displaying random emotions and gestures contributed for the participants to declare that the agents displayed their personality, even though it seemed nonsensical.

4.4.2.7 Questionnaire reliability

In order to assess the reliability of the believability measuring questions, we decided to do a Cronbach's alpha test.

We found that our alpha value of 0,904 would lower if any dimension is removed. We conclude that no dimension should be removed.

4.4.3 Interpreting the agents intents

As we stated in section 4.3, after the participant, for each video, ranked the six believability measuring items, he would proceed to answer multiple-answer questions to assess his interpretation of the scene.

The results for each video are as following:

It was our intention when developing the video with the anticipation module (see 4.2.1), to portray a situation where the bottom player requested a ball and the top player, which wanted to score, relents and passes to its teammate instead. The result of the participants interpretation shown by figure 4.16.

We can conclude that, in the video with the anticipation module, 76,9% of the participants identified the intentions of the top player as we intended. It is interesting to note that, the only means of interaction between agents was through the anticipation module, but that did not deter the participants from interpreting the interaction. As such, in the videos without anticipation and without both the anticipation and reaction, the majority of the users believed the top player passed the ball to its teammate because it wanted to in the first place, even though, as we can see by the bar graph, the participants are much less decided about it. This leads us to conclude that the participants tend to assume a behaviour to be voluntary and intentional unless some form of conflict is made explicit.

In regards to the bottom player 4.17, the advantages of the anticipation module are even clearer, with 92% of decisiveness.

4.4.4 User ordering

In the question that asked users to order the videos by believability, the video which featured agents with both the anticipation and the reactive emotion module (Video A) was in first place in 71.2% of the answers. The video which featured the reactive emotion module but not the anticipation module (Video B) was tied with the video which featured random animations (video D), both being placed first by 13.5% of the users. The video which featured agents with neither anticipation no reactive emotion module or random animations was put in first place by only 1.9% of the users. The video with random emotions was ordered in fourth and last place by 50.0% of the users. See figure 4.18.

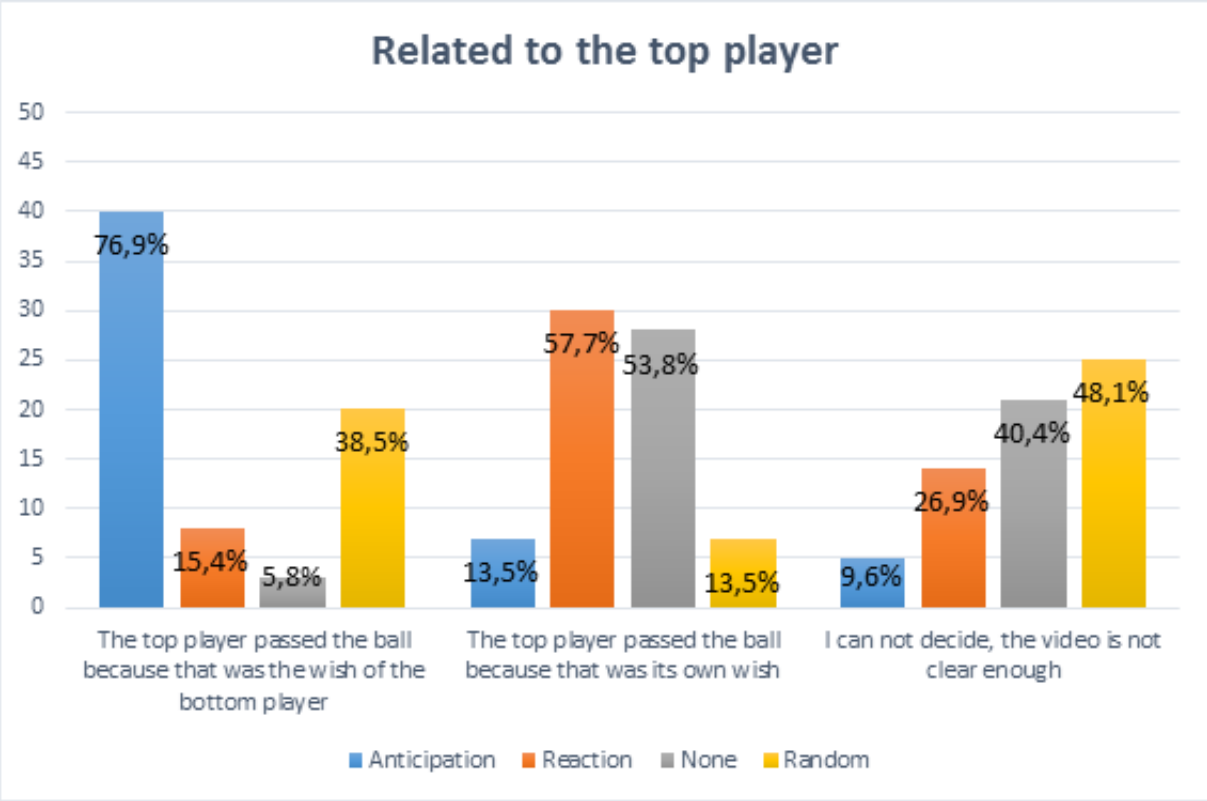


Figure 4.16: Frequency graph of participants interpretation of the behaviour of the top player in the videos in which the bottom player shot

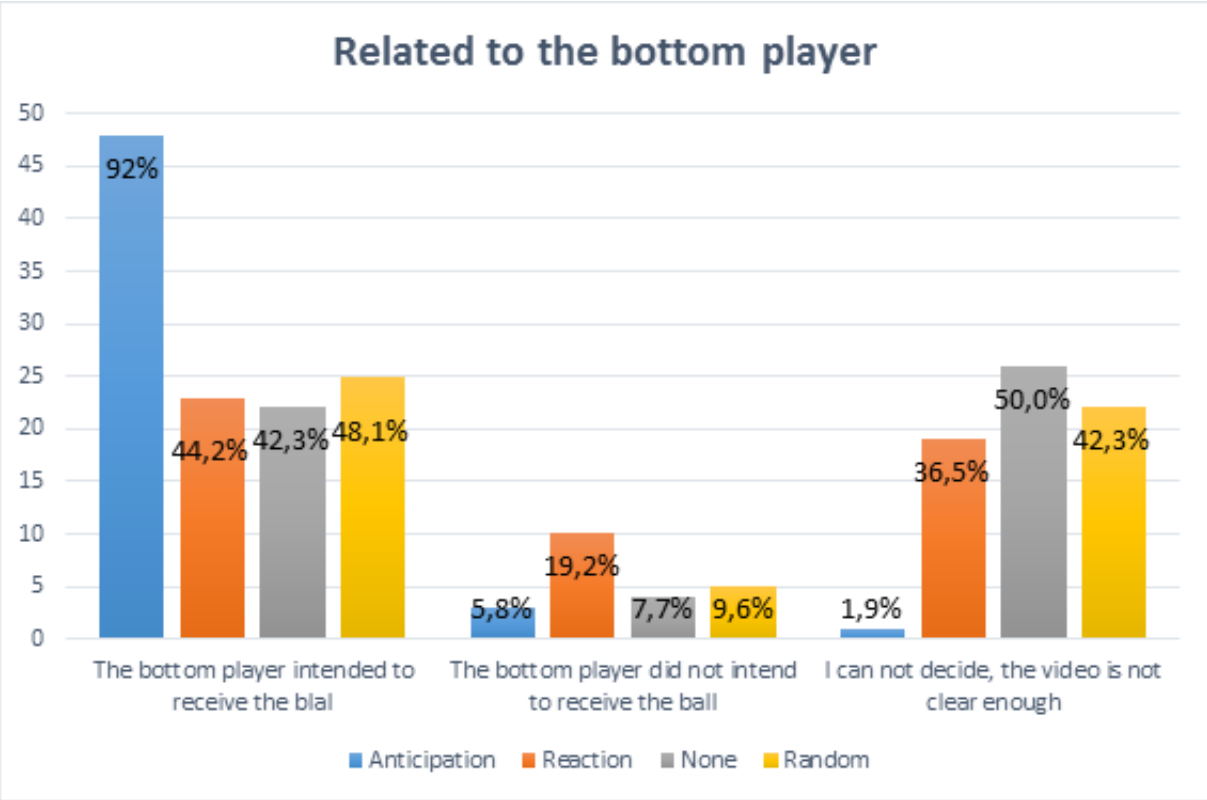


Figure 4.17: Frequency graph of participants interpretation of the behaviour of the bottom player in the videos in which the bottom player shot

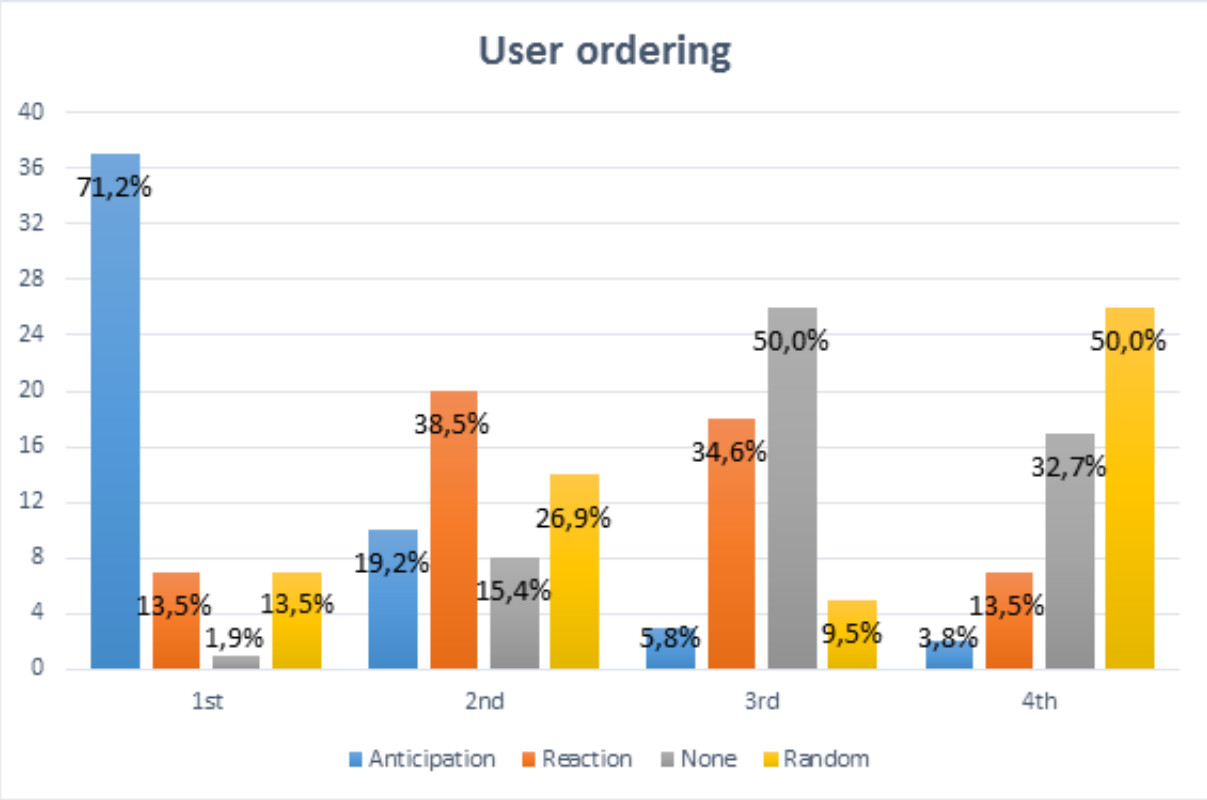


Figure 4.18: The frequency graph of the user ordering of the videos. Video A , with the anticipation module, was clearly the preferred video between the users.

Using Wilcoxon signed-rank test to assess the difference in preference between the videos yields the results displayed by table 4.7.

	Anticipation	Reaction	None
Reaction	Z = -6,006 p-$value$ = 0,000	-	-
None	Z = -6,418 p-$value$ = 0,000	Z = -5,796 p-$value$ = 0,000	-
Random	Z = -5,831 p-$value$ = 0,000	Z = -4,811 p-$value$ = 0,000	Z = -1,732 p-$value$ = 0,083

Table 4.7: p-$value$ results of the Wilcoxon signed-rank test when comparing each video in the ordering

We can conclude that there is no statistically significant difference in the ordering between the video with reactive agents and the video without the reactive module and anticipation module.

4.5 Discussion

Our analysis of the data we collected through the questionnaire led us to conclude that the video with the anticipation module was consistently ranked higher across every dimension, which means that the participants perceive the video featuring our approach to be more believable than the remaining videos.

The participants also found the video with the anticipation module much clearer and easier to understand than the remaining videos. Only 9,6% were left undecided about the intention of the top player in the video with the anticipation module, against 26,6%, 40,4% and 48,1% in the videos with only the reaction module, without the anticipation and reaction module and with random animations respectively. Regarding the bottom agent the results were even more pronounced, with 1,9% of uncertainty in the video featuring our approach against 36,5%, 50,0% and 42,3% in the remaining videos respectively.

Lastly, when asked which approach portrayed agents as ”life-like, believable creature with interesting human-like qualities, and less like pre-programmed (ro)bots?”, 71,2% of the participants selected our approach as their preferred approach. The second most preferred approach was the video with the reactive agents, and the least preferred approaches were the video featuring neither the anticipation module nor the reactive module and the video featuring agents displaying random emotions and gestures.

Chapter 5

Conclusion

With this work we aimed to create a new level of interaction between synthetic characters. A new level which would permit clearer communication, conflict and cooperation. These synthetic characters have their own expectations and desires which they seek to fulfill. If they fail they get frustrated. They also possess other human-like qualities to them, like confidence which is circumstantial. With these traits we hoped to created a new approach for believable interaction between synthetic characters.

We started by presenting our motivation in this subject, and the most common approaches in today's videogames to create the perception of believability in synthetic characters. We also pointed out why we believe those approaches were not perfect and how there was room for improvement.

Our work draws influence from the principles of traditional animation, particularly the idea of dividing an action in two stages: The anticipation stage, in which the character displays an intent, and the execution stage, in which the action *per se* is executed. We made an overview of some new approaches of agent cooperation and agent communication, and we presented an effective approach to measure perceived believability by testing several dimensions using Likert scales. We adapted these dimensions to our work at hands while staying true to its core idea.

We proceeded to present our approach for believability which consists primarily in dividing an action in two stages: anticipation and execution and we implemented our solution in a video-game called Soccer Pucks. We described the agent architecture, and how each module would be interacting with another. The agent uses gestures to communicate with its teammate and displays emotion regarding the outcome of its actions or the actions of its teammate. It is able to ask for the ball, reject a pass, and show an intent to pass or to shoot. It may get angry, frustrated and display joy.

To validate our approach we developed a scenario that would feature two agents that communicated with each other to score a goal. This scenario led to four videos: a video with our anticipation module, a video without our anticipation module, another video without both the anticipation module and the reactive module, and, lastly, a video with neither module but featuring random animations.

Analysing our data gathered from the questionnaires led us to conclude that our approach is highly successful: The participants showed a clear preference for the video with the anticipation module in every believability dimension as well as in the ordering. The participants also felt the video with the anticipation featured clearer interactions that were easier to interpret that the two other approaches.

5.1 Future work

There is still a lot of work that can be done around this approach. Early in our work we intended to develop a version of *Soccer Pucks* which would enable the player to cooperate and play against the artificial characters and a full featured match. However, midway through development, in early playtesting, we found that this approach was not the best to objectively evaluate our model. We decided instead to go for a more controlled approach, that would not be dependent on player skill and experience with video-games. Now, after having validated our model, we feel that it would be interesting to see it implemented in a playable scenario.

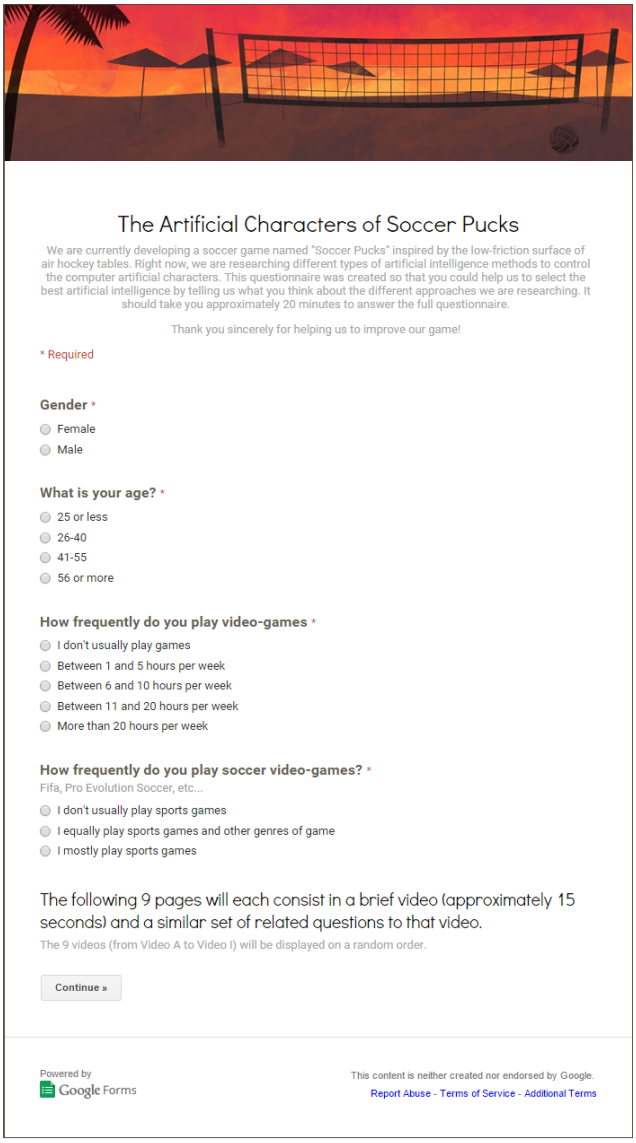
The transition to a real-time sports game isn't trivial however. The decision making module would have to be fully developed, and believable decision making is not straightforward, as any mistake may break the player's suspension of disbelief. Nevertheless, it would be interesting to adapt the model to other genres of games that could benefit a new layer of believable interaction, such as in adventures games like Skyrim, where the player's attention was not focused on his companion at all times, so a mixture of body language and vocalization could be required to draw the player's attention when needed.

It would also be interesting to expand the mental model of the architecture. For some experiences, learning and preemptive capabilities could lead to interesting possibilities. We wonder how this approach could lead a virtual Robocup match to be more exciting. Would a comentator be able to tell the story of the game like in a real match?

Appendix A

Appendix - Forms

One of the questionnaire variants that we used. Created with Google Forms [1].



The Artificial Characters of Soccer Pucks

We are currently developing a soccer game named "Soccer Pucks" inspired by the low-friction surface of air hockey tables. Right now, we are researching different types of artificial intelligence methods to control the computer artificial characters. This questionnaire was created so that you could help us to select the best artificial intelligence by telling us what you think about the different approaches we are researching. It should take you approximately 20 minutes to answer the full questionnaire.

Thank you sincerely for helping us to improve our game!

* Required

Gender *
- Female
- Male

What is your age? *
- 25 or less
- 26-40
- 41-55
- 56 or more

How frequently do you play video-games *
- I don't usually play games
- Between 1 and 5 hours per week
- Between 6 and 10 hours per week
- Between 11 and 20 hours per week
- More than 20 hours per week

How frequently do you play soccer video-games? *
Fifa, Pro Evolution Soccer, etc...
- I don't usually play sports games
- I equally play sports games and other genres of game
- I mostly play sports games

The following 9 pages will each consist in a brief video (approximately 15 seconds) and a similar set of related questions to that video.

The 9 videos (from Video A to Video I) will be displayed on a random order.

Continue »

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[1] http://www.google.com/forms/about/

The Artificial Characters of Soccer Pucks

* Required

Please indicate your agreement with the statements presented below the video.

You may re-watch the video as many times as you want while answering to the questions.

Video B

The following questions are related to the video above.

The intentions of the artificial players are easy to understand. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly Agree

The artificial players are aware of their surroundings. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly Agree

It is easy to understand where each artificial player is focusing its attention on. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly Agree

The artificial players communicate with each other. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly Agree

The emotions of the artificial players are easy to understand. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly Agree

The artificial players clearly display their personality. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly Agree

Related to the top artificial player: *

- ○ The top player passed the ball because that was the wish of the bottom player.
- ○ The top player passed the ball because that was its own wish.
- ○ I can not decide, the video is not clear enough.

Related to the bottom artificial player: *

- ○ The bottom player intended to receive the ball.
- ○ The bottom player did not intend to receive the ball.
- ○ I can not decide, the video is not clear enough.

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The Artificial Characters of Soccer Pucks

* Required

Please indicate your agreement with the statements presented below the video.

You may re-watch the video as many times as you want while answering to the questions.

Video I

The following questions are related to the video above

The intentions of the artificial players are easy to understand. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly Agree

The artificial players are aware of their surroundings. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly Agree

It is easy to understand where each artificial player is focusing its attention on. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly Agree

The artificial players communicate with each other. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly Agree

The emotions of the artificial players are easy to understand. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly Agree

The artificial players clearly display their personality. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly Agree

Related to the top artificial player: *

- ○ The top player passed the ball because that was the wish of the bottom player.
- ○ The top player passed the ball because that was its own wish.
- ○ I can not decide, the video is not clear enough.

Related to the bottom artificial player: *

- ○ The bottom player intended to receive the ball.
- ○ The bottom player did not intend to receive the ball.
- ○ I can not decide, the video is not clear enough.

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The Artificial Characters of Soccer Pucks

* Required

Please indicate your agreement with the statements presented below the video.

You may re-watch the video as many times as you want while answering to the questions.

Video H

The following questions are related to the video above

The intentions of the artificial players are easy to understand. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	◉	Strongly Agree

The artificial players are aware of their surroundings. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly Agree

It is easy to understand where each artificial player is focusing its attention on. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly Agree

The artificial players communicate with each other. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly Agree

The emotions of the artificial players are easy to understand. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly Agree

The artificial players clearly display their personality. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly Agree

Related to the top artificial player: *

- ○ The top player passed the ball because that was the wish of the bottom player.
- ○ The top player passed the ball because that was its own wish.
- ○ I can not decide, the video is not clear enough.

Related to the bottom artificial player: *

- ○ The bottom player intended to receive the ball.
- ○ The bottom player did not intend to receive the ball.
- ○ I can not decide, the video is not clear enough.

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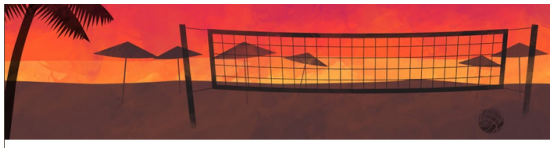

The Artificial Characters of Soccer Pucks

* Required

Please indicate your agreement with the statements presented below the video.

You may re-watch the video as many times as you want while answering to the questions.

Video A

The following questions are related to the video above.

The intentions of the artificial players are easy to understand. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly Agree

The artificial players are aware of their surroundings. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly Agree

It is easy to understand where each artificial player is focusing its attention on. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly Agree

The artificial players communicate with each other. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly Agree

The emotions of the artificial players are easy to understand. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly Agree

The artificial players clearly display their personality. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly Agree

Related to the top artificial player: *

- ○ The top player passed the ball because that was the wish of the bottom player.
- ○ The top player passed the ball because that was its own wish.
- ○ I can not decide, the video is not clear enough.

Related to the bottom artificial player: *

- ○ The bottom player intended to receive the ball.
- ○ The bottom player did not intend to receive the ball.
- ○ I can not decide, the video is not clear enough.

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The Artificial Characters of Soccer Pucks

* Required

While developing our game, we used different artificial intelligence approaches to control our artificial players. The next four videos show four different approaches we explored:

Video A

Video B

Video C

Video D

Which video portrays the characters as more life-like, believable creatures with interesting human-like qualities, and less like pre-programmed (ro)bots? Please order the videos from your most preferred approach to your least preferred approach. *

	Video A	Video B	Video C	Video D
1st				
2nd				
3rd				
4th				

As a last question, please (briefly) explain the reason for your choice and (optionally) what could be improved in the approach you preferred the most. *

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Appendix B

Appendix - Wilcoxon signed-rank test Tables

	Reactive - Anticipation	None - Anticipation	Random - Anticipation	None - Reactive	Random - Reactive	Random - None
Negative Ranks	26	37	38	19	30	22
Positive Ranks	5	4	2	10	8	10
Ties	21	11	12	23	14	20
$p\text{-}value$	0,000	0,000	0,000	0,038	0,000	0,022

Table B.1: Wilcoxon signed-rank test results for the dimension ”The intentions of the artificial players are easy to understand”

	Reactive - Anticipation	None - Anticipation	Random - Anticipation	None - Reactive	Random - Reactive	Random - None
Negative Ranks	19	27	27	20	26	12
Positive Ranks	11	8	5	5	9	14
Ties	22	17	20	27	17	17
$p\text{-}value$	0,101	0,001	0,000	0,001	0,002	0,327

Table B.2: Wilcoxon signed-rank test results for the dimension ”The artificial players are aware of their surroundings”

	Reactive - Anticipation	None - Anticipation	Random - Anticipation	None - Reactive	Random - Reactive	Random - None
Negative Ranks	23	34	28	22	23	20
Positive Ranks	6	8	4	9	6	15
Ties	23	10	20	21	23	17
$p\text{-}value$	0,004	0,000	0,000	0,012	0,002	0,196

Table B.3: Wilcoxon signed-rank test results for the dimension ”It is easy to understand where each artificial player is focusing its attention on”

	Reactive - Anticipation	None - Anticipation	Random - Anticipation	None - Reactive	Random - Reactive	Random - None
Negative Ranks	38	43	34	21	18	8
Positive Ranks	2	1	5	6	21	26
Ties	12	8	13	25	13	18
$p\text{-}value$	0,000	0,000	0,000	0,003	0,216	0,002

Table B.4: Wilcoxon signed-rank test results for the dimension ”The artificial players communicate with each other”

	Reactive - Anticipation	None - Anticipation	Random - Anticipation	None - Reactive	Random - Reactive	Random - None
Negative Ranks	26	41	35	31	24	7
Positive Ranks	6	4	6	5	12	23
Ties	20	7	11	16	16	22
$p\text{-}value$	0,001	0,000	0,000	0,000	0,068	0,038

Table B.5: Wilcoxon signed-rank test results for the dimension ”The emotions of the artificial players are easy to understand.”

	Reactive - Anticipation	None - Anticipation	Random - Anticipation	None - Reactive	Random - Reactive	Random - None
Negative Ranks	31	33	20	21	13	5
Positive Ranks	6	4	7	7	21	25
Ties	15	15	25	24	18	22
$p\text{-}value$	0,000	0,000	0,015	0,002	0,103	0,002

Table B.6: Wilcoxon signed-rank test results for the dimension ”The artificial players clearly display their personality”

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