SenToy in FantasyA: Designing an Affective Sympathetic Interface to a Computer Game

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Abstract: We describe the design process of an affective control toy, named *SenToy*, used to control a synthetic character in a computer game. SenToy allows players[1] to influence the emotions of a synthetic character placed in FantasyA, a 3D virtual game. By expressing gestures associated with anger, fear, surprise, sadness and joy through SenToy, players influence the emotions of the character they control in the game. When designing SenToy we hypothesized that players would manipulate the toy to express emotions using a particular set of gestures. Those gestures were drawn from literature on how we express emotions through bodily movements and from emotion theories. To evaluate our idea we performed a Wizard Of Oz study [1]. The results of the study show that there are behaviours that players easily pick up for expressing emotions through the gestures with the toy, though not necessarily the ones extracted from literature. The study also provided some indication on what type of toy we should build, in particular, its 'look and feel'.

Keywords: Affective interfaces; Game; Gesture-based interaction; Wizard of Oz study

1. Introduction

Gaming is a highly relevant application area for Intelligent Agents and Human Computer Interaction (HCI). Computer games bring us a full set of new gaming experiences where synthetic characters take on the main role. Turn to, for example, *Tomb Raider* and the impact of a character like Lara Croft. Although purely fictional, the character has a personality, likes and dislikes, friends, etc., that pulls us into the story and make us feel as a part of it. Using affective input in the interaction with a game, and in particular with a character, is a recent and fairly unexplored dimension, and to our knowledge, there is no other system like the one we are developing and describing here.

Indeed, as the research area of autonomous life-like characters matures and characters become more believable, the interaction between users/players and those characters will change. Influenced not only by face-to-face communication, but also by recent developments in multi-modal communication and tangible interfaces, users can now directly speak to the character, exhibit facial expressions and, through that, influence the behaviour of the synthetic character. However, in most of cases, the interaction between characters and game players presupposes that there is a clear boundary between the character (who is living in the virtual world) and the player (living in the real world). The character is 'virtual', and its presence is constrained to that virtual world. On the other hand, users may live in both worlds, the real one and the cyberworld, through their avatars. But, as argued by Ishii [2]: "Despite this dual presence of the users (in the real and virtual world), the absence of seamless couplings between these two parallel existences leaves a great divide between the two worlds".

It was this division that inspired research on 'tangible user interfaces', where the goal is to [2] "go beyond the current GUI (Graphic User Interface) and bring current objects to the interaction between users and computers". Inspired by the tangible user interface vision, new types of interfaces have been built as means of bridging the gap between these two worlds. Objects in the real world can be given extended capabilities that allow users to merge the real world with the virtual world. This idea is of

[1]We use the term 'player' rather than 'user' throughout the paper to emphasize that the target domain is a game.

particular interest for synthetic characters as such objects may allow us to identify physically with our virtual character. Recently a team at the MIT Media lab developed what is called a "sympathetic interface" [3], named Swamped!. In the system Swamped!, the user takes on the role of a chicken that is trying to protect its eggs from a hungry raccoon. For example, the user can wobble the doll back and forth, which will make the virtual chicken walk. Such an interface can be seen like a 'physical' incarnation of the synthetic character, and allows the user to manipulate and touch it to influence the character's behaviour in the virtual world.

With the design of SenToy we are aiming at creating such a sympathetic interface allowing for touch and gestures, to be used to control a character in a game (FantasyA). Players in the game FantasyA have to master SenToy and exhibit a particular set of emotions and perform a set of actions in order to evolve in the game (see Paiva et al. [4]). Players' characters will be drawn into duels where the expressed emotion determines which spell is cast at their opponents, the players' character will trade (using emotion expressions) with other characters to win magic stones, and so on. The aim of SenToy is to 'pull the player into the game' through the use of a physical, touchable affective interface. With sensors in its limbs, sensitive to movement and acceleration, SenToy is designed to capture certain manipulations patterns from players, which in turn are associated with particular emotional expression.

2. Design Questions

However, the design of SenToy posed some major design questions:

- What kind of gestures would be the best ones to express the set of emotional states we need for the game FantasyA?
- What type of doll is most appropriate for this kind of interface?
- Will players like it?

Studies on gestures and emotion show that high arousal and high intensity is associated with arms up, away from torso, whereas head down is associated with negative valence. Observations performed by Kirsch and Picard [5] with the 'Affective Tigger' describe some experiments where children bent Tigger's head forward to make him sad and bounced him to express happiness. However, are these findings extensible to 'more adult' players controlling a toy that is embodied in a 3D game?

To answer some of these questions, and thus inform the subsequent design of SenToy, we performed a Wizard of Oz study [1], where players were placed in front of a 'controllable' synthetic character (Papous) and were asked to control the character's emotions through a (fake) plush toy.

The results achieved by this experiment show that for certain emotions (happiness, anger, fear, sadness, surprise) there are clear recognizable pattern of gestures that players followed for controlling the emotional state of the character. We also found that behaviour such as walk or pick an object were rated as more easily expressed than emotion gestures. On the other hand, in particular disgust was reported to be difficult to express by the players. In this paper, we describe the concept of SenToy, the experimental study done as a Wizard of Oz study, its results and impact on the SenToy design and integration in FantasyA.

3. FantasyA and the SenToy Concept

"FantasyA is a world guided by the Dreams of four mighty Gods who, although imprisoned in the godly stones, the KemY's, use the Dreams to impose their will over the inhabitants of the Land. Guided by the Gods, the IdenjaYeh built the Covenants, the strongholds of the Clans, symbol of Learning and Power. There, the Magi of each Clan, after being called to the Covenant through the Dreams, are trained in the art of AlkemHYe, the art of Elemental control." Extracted from FantasyA concept [6].

Players act the role of an Apprentice Magus of one of the Four Clans of FantasyA (Fig. 1). The Magus has finished training in AlkemHYe and passed the Initiation Ceremony, and is ready to leave the Covenant. After an initial background explanation of the world and the clans, the player chooses a clan and a character (through the character creation tool) and enters the FantasyA world. In FantasyA, characters are magi that can act in the world by moving, manipulating magic gems, and interacting with other agents through duelling or trading. Most importantly, the interpretation of each inter-

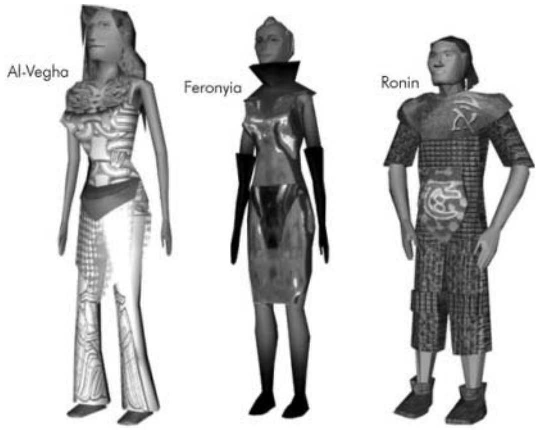

Fig. 1. Al-Vegha: a character in the Water clan. Feronyia: a character in the Fire clan. Ronin: a character in the Earth clan.

action with the others will be dependent on the emotions of the character and thus the emotional control the player has over the character. Battles between characters are won through the adequate emotional control of the character.

3.1. The idea of SenToy

Given the characteristics of the FantasyA plot, we decided to start with six different emotional states as identified by Ekman [7] and then try to determine how a user would express those emotional states through the manipulation of a doll. Users can perform two kinds of actions through the SenToy: *movement actions* and *emotion related actions*. Movement actions include walking, picking up items, and stopping. Emotion related actions concern making the avatar's emotional state change to exhibit one of six different emotions: happiness, sadness, anger, disgust, surprise and fear.

The initial identification of the gestures was based on emotion theories (in particular Lazarus theory [8]) and work on movement and dance (in particular Laban's theory [9]). We also studied how cartoons move and express emotions [10]. Table 1 provides the description of the hypothesized gestures for the six chosen emotions.

Note that the rhythm, vitality and intensity of the movement with SenToy may also be used to determine the emotional value. For example, if the player makes the toy dance and jump with a high vitality, the corresponding emotion (joy according to the mapping tables) will have a higher intensity than it would have if the same stimuli had been performed through more smooth gestures.

4. Experiment: Informing the Design of SenToy

Our first goal was to show that it is possible to express emotions and behaviours through a doll to control a character in a virtual world. In addition, we needed to know exactly which movements and behaviours of the doll players would most easily pick up. We anticipated two reasons why the rules in Table 1 would not necessarily work. First, because players will not behave in the same way when expressing emotions through the doll as when expressing emotions through their own body. Secondly, players had to be put in a context where feedback from their character's reactions to their manipulation is given so that *learning* the

Table 1. Table of emotions and gestures

Emotion	Gestures	Reference
FEAR	Put SenToy's hands in front of its eyes or move it backwards vigorously.	According to Lazarus [8] fear is associated with avoidance.
ANGER	Place SenToy's arms crosswise or shake it vigorously.	According to Lazarus [8] anger is associated with the "tendency to attack".
SURPRISE	Open SenToy's arms backwards inclining its torso slightly backwards.	According to Laban [9] surprise is associated with attention and with a sudden event and inclination of torso backwards. "A surprised person often raises his opened hands high above his head, or by bending his arms only to the level of his face".
SADNESS	Bend down SenToy's neck or bend down the entire torso.	According to Scherer [12] sadness is expressed through slow movement inwards and head down.
HAPPINESS	Swing SenToy (make it dance) and/or play with its arms.	Joy is portrayed with open arms, movements such as clapping or rhythmic movement according to Darwin [4].
DISGUST	Move SenToy slightly backwards (squeezing it slightly).	According to Lazarus [8] action tendencies for disgust include "move away", nausea and even vomiting.

Table 2. Table of Actions

Movements	Gestures
WALK	Swing the legs forward and backward alternately or move the SenToy forward with small jumps.
STOP	A bouncing jump vertically.
PICK	To bend down and move the arm like it was picking something or moving the SenToy like it was diving.

appropriate manipulation of the SenToy is possible. Thus, building the whole SenToy system, with sensor recognition, affective interpretation and physical layout connected to the character on the screen, from the description in Table 1 and 2 without some initial experimentation, would have been a waste of time and resources. Instead, we decided to make use of the Wizard Of Oz study method. In a Wizard of Oz study, the user is made to believe that they are interacting with a system, while in reality the user is interacting with a human Wizard pretending to be the system.

Designers and researchers are often misled into believe that humanhuman communication should be used as the best model for interaction between human and machine. A Wizard study early in the project can reveal principles and peculiarities particular to the design of human machine interaction [1].

5.1. Software description

The experimental setting should mirror a situation where a player is handling a doll to control the emotions of a synthetic character. Players must have feedback from the character, as a response to their handling of the toy. This was achieved by developing a module that would allow the Wizard to control the emotions and actions displayed by the character according to the observed gestures and actions performed by the players. This module contains two components: one running on the client and one running on the Wizard machine. Both of them perform the actions and emotions that are controlled by a set of buttons displayed on the Wizard's machine (see Fig. 2).

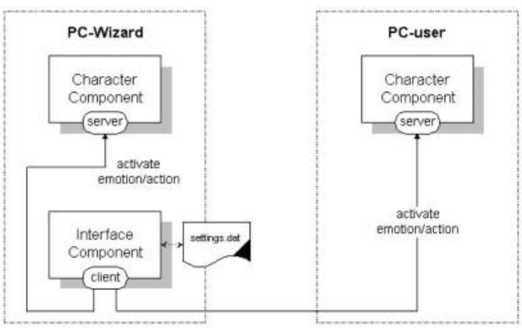

Fig. 2. Architecture of the software used for the experiment.

5.2. The character Papous

We reused a character named Papous from a previous project to have a character on the screen. Papous is able to convey emotions through gesture, facial expressions, voice and text. The character used is a granddad that tells stories [11] and thus adapts what he says to the gestures (actions) of the player handling the toy.

The facial expressions for the emotions were based on Ekman's basic emotions and a professional designer designed the animations.

Figure 3 shows the snapshots of the synthetic character corresponding to the emotional states it can express through facial expressions and speech. In Silva et al. [11] a detailed description on how Papous combines emotional speech and gestures is presented.

The vocal expressions are also part of the animations of the emotional states. Each emotional state has associated a text file in which we can insert up to ten different sentences. The system will choose randomly the sentence to use during run-time, each time each emotion is activated. These sentences are meant to complement the associated emotional state.

The speech is generated through an Affective

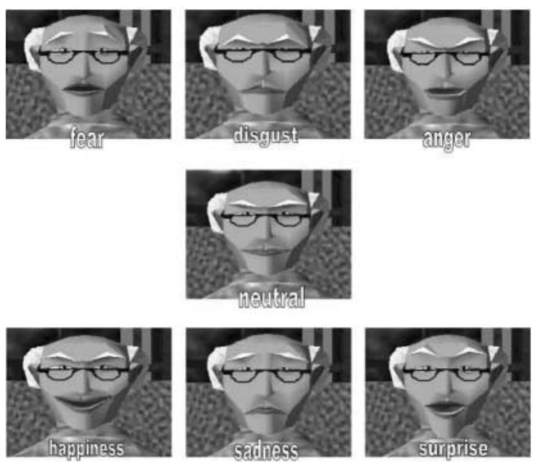

Fig. 3. Screenshots of Facial Expressions in Papous.

Speech component that receives sentences together with the current emotional state and then produces synthesized speech expressing the current emotion. The precision with which we control the character's voice depends mostly on the underlying text-to-speech (TTS) system. We used a TTS system (Eloquent) that allows the control of seven parameters to define the voice.

To transmit emotions through the voice of Papous (see also Silva et al. [11]) we established a series of relations between emotions and voice parameters using theoretical knowledge about the way emotions affect speech [12]. For example, to express happiness we increase the speed parameter, increase the pitch baseline and pitch fluctuation.

Instead of the TTS we could have used a set of pre-recorded sentences for the experiment, with an actor portraying the emotions. However, believability in the synthetic character was not an issue for the experiment, and in fact, given that we wanted the player to feel in control of the character and to mimic the situation of a game, the synthetic speech was more appropriate because it is 'artificial'.

Finally, the character may also perform a set of actions that use animations with full body expressions. These body expressions correspond to actions of walking, an action of stopping, which makes the characters stand up; and finally an action that corresponds to a picking movement (see Fig. 4). The picking up movement is important for the context of the game.

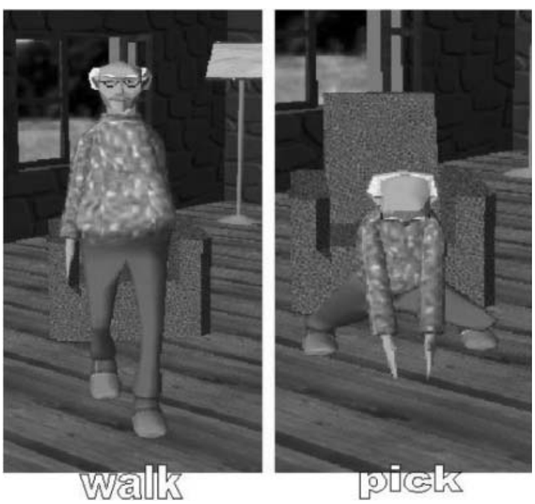

Fig. 4. Screenshots of the controlled actions in Papous.

5.3. The study

In this study we did one pilot and one final run. The subjects in the pilot used a Barbie doll and a teddy bear as SenToy 'prototypes'. They were asked to move the dolls in order to express emotions, and that the doll contained sensors that would detect these movements. The computer would then interpret the movements and thereby they would be in control of the synthetic character shown on the screen in front of them. We also told them that the sensor signals were picked up by a video camera and that the equipment reacted to *speed*, *direction* and *distance* from the camera. The pilot (with two subjects) showed that we had to do some changes to the initial mapping rules (as described in Table 1), since the subjects did not use the distance dimension at all in order to express any emotion. When expressing disgust, subjects were supposed to move the toy backwards from the camera and if they didn't perform this movement, the system reaction was a neutral facial expression (see Fig. 3). When this happened, subjects perceived it as they had failed the task. We therefore altered the design and used the movements that the two subjects in the pilot had used to express disgust, i.e. 'vomiting' and wiping the arms over the dolls face as if wiping something away.

After the pilot we also decided to test a puppet instead of the Barbie doll for half of the subjects, in order to see if the subjects would be more inclined use the distance dimension using a different kind of doll. The final run was then performed as described below.

5.3.1. Subjects

In the study we used eight Swedish subjects, four males and four females, between 14 and 30 years old.

5.3.2. Procedure

The subjects went through the following steps:

1. First they were shown six screen shots (see Fig. 3), where the avatar expressed the six different emotions and they were asked to pair the screenshot with one of the six emotions (written on a paper). Afterwards, they were told the right answers, so that they would recognize the avatar's facial expression when performing the experiment.
2. Subjects were told to control a synthetic character on the screen through manipulating

one of two dolls. They were told that the doll contained sensors that reacted on movements and distance and that the video camera picked up the sensor signals. The Wizard asked them to move the doll to express one of the six different emotions at a time, and similarly with the three movement actions. The synthetic character on the screen reacted to their movements and expressed the emotions or performed the actions that were related to the movements performed by the subjects. If the performed the wrong movement (according to Tables 1 or 2) the result was a neutral expression or no movement. In reality, of course, it was the Wizard who initiated the system response and the video camera was just a plain video camera. Emotion-related actions, listed above, changed Papous' facial expression and made him say a few words. It did not result in full body expressions of the avatar only the face and torso of the avatar was shown as in Fig. 3. Half the subjects were asked to perform the movement actions before the emotion related actions; the other half performed the emotion-related actions first. The subjects used two different dolls all subjects used a teddy bear, and four of them used a Barbie doll and the last four a puppet. We varied the order of which doll they started with. If they found it too hard to express a certain emotion with the doll, the experimental leader took the next emotion on the list.

3. Subjects finally filled in a questionnaire, providing feedback of their impression of the experiment, which doll they preferred to use, and how hard they felt it was to express different emotions with the doll.

5.3.3. The setting

The subjects sat in a chair with the video camera placed at a distance of two meters from the chair. The screen with Papous was placed to the right. The chair was placed so that the subjects could see both the screen and the camera if turning their heads. Thus, subjects would turn to the camera to do the doll movement properly, and then they would turn towards Papous. The Wizard sat behind a desk beside the camera.

5.3.4. The Wizard's task

The Wizard asked the subject to perform an emotion-related action or a movement action and she had a set of control buttons that she could push to make the avatar express a particular emotion or movement action. The Wizard's task was quite difficult, as she had to recognize whether, unintentionally, the subject had expressed another emotion than the one asked for. In such a case, she had to make the avatar express the wrong emotion. This meant interpreting a continuous stream of various doll movements created by the subject.

5.3.5. The dolls tested

We used three different dolls in this experiment: one teddy bear, one Barbie doll, and one puppet (see Fig. 5). The teddy bear was quit soft and the subject could move his arms and legs. It was about 30 cm high and had a neutral facial expression. The Barbie doll Super Model Kenneth was a traditional male Barbie doll made of plastic. It was possible to move his arms and legs. Since the Barbie doll's hands and feet were too small to reasonably be able to contain sensors, we taped fake 'sensors' on his hands and feet so that the subjects would get the impression that there were actually sensors on the doll.

The puppet was a female doll, 'Pippi Longstocking', about 15 cm high. It was possible to put your fingers inside the doll's arms and then move her arms around. There were no holes in the doll's legs, so the subjects could not move the legs. Also this doll had fake 'sensors' to give the subjects the impression that there were sensors on the doll.

Fig. 5. Set of Dolls Tested.

6. The Results

We divide the results obtained in the experiment into the following categories: the dolls tested; the setting of the experiment; portraying emotions through gestures; the comparison between the gestures for actions and for emotions and finally the subject's views after the experiment. All these results had a subsequent impact, directly or indirectly on the final design of SenToy.

6.1. Dolls tested

Seven of the eight subjects preferred to use the teddy bear to express emotion and perform actions (see Fig. 6). The last subject preferred to use the puppet. The reason given was that they perceived that toy easier to handle and more mobile. It was important for the doll to be soft enough to be bent in various directions. This was a crucial problem with the Barbie doll that was made of hard plastic. Even if it was possible to bend his limbs, it was hard to portray continuous movements back and forth. When using the Barbie doll, the subjects were quite absorbed by moving his arms and legs, and then they had difficulties focusing on the avatar on the screen. The size of the doll was also deemed important. If the doll is too small, the movements become hard to perform.

Subjects preferred toys with a neutral facial expression, as it was easier to portray emotions other than those expressed by the doll's facial expression. This was a problem in the case of the puppet (see Fig. 5), which had a happy face. The Barbie doll and the teddy bear had fairly neutral facial expressions.

The subjects were also asked if they would like to change anything or add anything to the dolls, and some of them wanted to be able to change the dolls facial expression. Some of the subjects wanted to be able to move the puppet's legs, by putting fingers inside its legs.

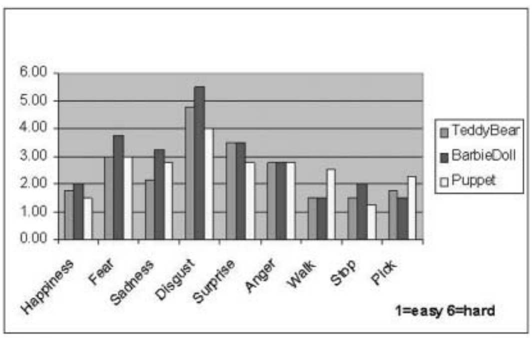

Fig. 6. Results from the dolls chosen.

6.2. Portraying emotions through gestures with the toy

One of the most important goals of this study was to determine which movements subjects would use 'naturally' to express certain emotions and whether those corresponded to the gestures the designers of the SenToy had envisioned (see Table 1). We could not be certain that these gestures would be the same, as they would use to express emotions through a toy. It should be pointed out here that we do not necessarily need to imitate the natural expressions that the subjects use. First of all, it might not be feasible to construct a doll with real sensors that is able to distinguish the sensory feedback that those "natural" expressions might produce from one another. Secondly, players may learn which movement to use in each situation through the feedback they get from Papous' expressions, thus they will be able to learn 'unnatural' movements. Still, if movements are not at all natural to players or hard to distinguish from one another, they might cause the player to give up the whole enterprise before learning how to behave. Thus, it was important to collect the 'natural movements' and compare those with the ones we had envisioned.

When expressing the emotion related actions the subjects often tried more than one set of movements before the system reacted. As it turned out, all of the movement actions and three of the emotion related actions (happy, surprise and sad) were expressed according to the rules suggested in Tables 1 and 2 by all of our subjects.

Table 3 shows the most common gesture and Table 4 shows the second most common gesture the subjects used to express a certain emotion. Sometimes the subjects performed two gestures

Table 3. Most common gesture

Emotion	Most common action	No
Anger	Boxing with its arms	12
Fear	Hands in front of the eyes	8
Disgust	Arm in front of face as if wiping something away	10
Happiness	Dancing/jumping, continuous movement	16
Sadness	Bending down its trunk	16
Surprise	Arms in the air, frozen position	16

Table 4. Second most common gesture

Emotion	Second most common action	No
Anger	Shake the doll	6
Fear	Turn the doll away from the camera	7
Disgust	'Vomiting'	4
Happiness	Arms in the air, waving them back and forth	11
Sadness	Hands in front of the eyes	8
Surprise	Lifting the doll upwards into a frozen position	4

at the same time, for example when expressing sadness, they bent down the dolls neck and at the same time put it's arms in front of the eyes. As can be seen from Table 3 all 8 subjects (in the end) expressed happiness, sadness and surprise according to the initial rules with both dolls. For fear, anger and disgust, seven out of eight subjects used the most common gesture with at least one of the dolls.

Unfortunately the additional actions that the subjects performed with the toy could cause some gestures might to get mixed up. The expression for sadness, for example, could get mixed up with the expression for fear in the final SenToy system, since subjects in the study put the dolls' hands in front of its eyes in both cases. The design envisioned was that they would only do this when expressing fear. All of our subjects expressed sadness through bending the trunk forwards, but in half the cases subjects also put the doll's hands in front of its eyes and simultaneously bent the trunk forwards.

In the same way happiness could get mixed up with surprise in the final SenToy system, even if all of the subjects expressed both emotions as suggested. In both cases, subjects would open the arms backwards. In the case of surprise, the movement would stop in a frozen position when the arms where extended, while in the case of happiness they would continue to move the whole doll back and forth or move the arms back and forth.

To express fear, in eight of the sixteen cases (see Table 4), subjects put the dolls hands in front of its eyes. In the other cases they turned the doll away from the camera, making it look in another direction.

The expression for disgust was quite hard for subjects to figure out. It was supposed to include a movement backwards, but subjects did not, as mentioned above, use the distance dimension. In the pilot we saw that disgust was instead most often expressed through making one arm wipe across the doll's face as if trying to get rid of something. Other subjects would bend the doll forward and make sounds as if vomiting. These two behaviours were the most frequently used to express disgust. The latter movement, vomiting, will be very hard to distinguish from bending the doll forwards to express sadness (as there is no voice recognition in SenToy). None of the subjects succeeding in portraying disgust as intended: through moving backwards and squeezing the doll slightly.

The last emotion, anger, was supposed to be expressed through folding the doll's arms crosswise or shaking the doll vigorously. None of the subjects folded the doll's arms crosswise. Instead, most subjects would use the doll's arms to imitate fighting or boxing. This movement will be hard to distinguish from the movements they made to express happiness where the arms were also moved back and forth by many subjects. Shaking the doll vigorously might also be confused with the movement for happiness where they dance with the doll.

6.3. Timing

One possible way of distinguishing between different emotions where the gestures are shown in similar ways, is to look at how long it takes for the subjects to complete a movement with the doll. When expressing anger for example, the arm movements are made almost twice as fast compared to the arm movements when expressing happiness. It took about five seconds for the subjects to complete the sadness gesture bending down the doll's trunk and perhaps holding the arms in front of it's face, and when expressing sadness they always started to bend down the neck. When expressing fear this gesture (putting the hand in front of the eyes) took about two seconds to fulfil. When we compared surprise and happiness and how long it took to get the doll's arms up in the air, we saw that the surprise movement was much faster and when the doll's arms were in the air, the movement stopped for about two seconds. In the case of expressing happiness the subjects kept swinging the doll in the air.

The arm movements when expressing disgust was as fast as when expressing anger. The 'vomiting' gesture was much faster than the bending movement when expressing sadness.

These timing elements will be crucial for the processing of the signals coming from the SenToy. Even if their first attempt at a particular emotion failed, subjects continued, trying out other movements, and, except in the case of disgust, most subjects finally got the avatar to portray the correct emotion. This was partly because the Wizard would sometime be fairly liberal in interpreting how the subjects moved the doll.

6.4. Portraying movement actions versus movement actions

The movement actions were all performed as suggested in the initial rules (see Table 2) by all of our subjects. When expressing movement actions the avatar was shown in full body expression, it became a direct mapping of the movement the subjects performed with the doll. The subjects reacted quite differently to the two sets of actions. When performing the movement actions, they felt that they 'became' the avatar. Their movements of the doll gave immediate feedback, mirroring their actions. Most subjects looked happy at this point, feeling that they were in control of the avatar. But when performing the emotion related actions, they experienced more difficulties and the relationship between movement of the doll and avatar expression was not a direct mapping. Thus, at this point, they did not feel equally much in control of the avatar.

6.5. Subjects view after the experiment

In the questionnaire the subjects were asked to rank how hard it was to express the emotion related actions and the movement actions with the different. In Fig. 5 we can see that the movement actions were perceived as fairly simple, but it was perceived as more difficult with the puppet than with the other dolls. The emotion happiness was almost as easy as the movement actions. Sadness, anger, and fear were ranked in between. Finally, disgust was deemed as the most difficult to express. One can also see that the subjects felt that it was more difficult to express the emotions with the Barbie doll than with the other dolls.

7. The Design of SenToy

The results of the study influenced dramatically the design of SenToy. The impact can be examined in several different categories: the type of the doll, its 'look and feel', the gestures to be identified as ways of expression emotions, the hardware needed to capture of gestures; and the impact that this affective control will give in the game and its dynamics. Here we will describe the impact the results had in the hardware chosen and the look and feel of SenToy.

7.1. SenToy's look and feel

Based on the results above described we took a set of decisions concerning the look and feel of SenToy. The rationale behind the functional specification for the design of SenToy can be summarized as in Fig. 7.

Based on these considerations, we took the following decisions:

- According to the results, players preferred the soft and cuddly toy instead of the hard plastic one. Thus the doll's exterior should be of soft fabric, filled with latex and covered with a kind of skin. Its material and construction must take into account: production (allow for easy opening of the toy) and also for the way the player will feel and physically interpret the toy's sensitive areas thus allowing for important areas to be marked with a softer material.
- As for the anthropomorphism of the doll, it should only be partially anthropomorphic (to

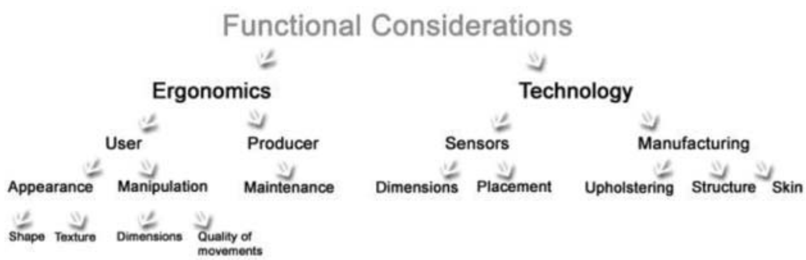

Fig. 7. Design of SenToy.

allow for legs, face and arms) with reference points to the avatar appearance in the virtual world. The prototype doll should be reasonably anthropomorphic but not human enough (with a recognizable facial expression) as to determine its manipulation by inducing preconceived behaviours. As suggested by the subjects, we decided that it should not have a defined facial expression, character or personality so that it will not constrain the manipulation and its adequacy to different synthetic characters and different emotions. Its minimalist appearance will allow for the same toy to be used for controlling many different types of characters.

- Given that the arms and legs of the toy were quite important for the gestures, we needed for arms, legs and torso to allow for the amplitude of movements big enough for an adult hand to hold. The quality of the doll's movements will always be conditioned by the adequate placement of the sensors but the supporting structure (the skeleton) and the enveloping upholstery should not hinder its flexibility while providing the required self-sustained stance.
- The upholstery and the dolls' skin should be determined by considering two main aspects; from the manufacturing perspective, it must be assured that, once the doll is assembled, it is possible to easily access its' interior for repairs, modifying or tuning the sensors and other components without damaging any of these elements. On the other hand, to the player the quality of the visual and tactile experiences of the skin's characteristics will be most important. Having said this, it is always possible to implement a graphic and/or textile bounding of areas on the doll's surface (thereby protecting its sensible components or enhancing the areas more suitable for manipulation) so as to create an image that borrows equally from the infantile doll as from the robotic gadget. This is the route we finally took for the design.
- The dimensions of the doll will primarily be determined by the size and the location of the hardware which it will contain and its' skeleton without neglecting the player's handling needs. It was important to break away from the miniature-like, fragile appearance of a toy, that can inhibit the player's actions, and move towards a larger doll that also would benefit from an empathy that comes with the approximation to the human scale.

Fig. 8. SenToy 3D model.

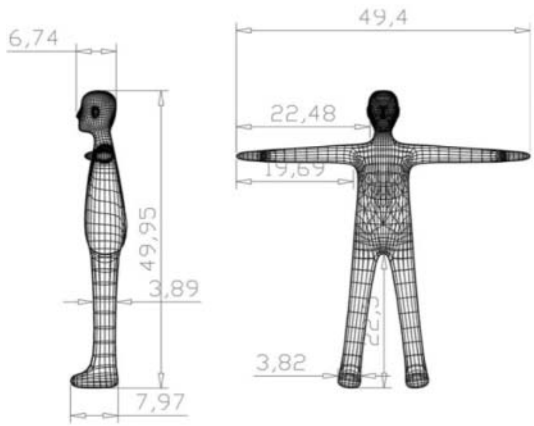

Fig. 9. SenToy model with measures.

- Finally, given the characteristics of FantasyA, the image of the toy stands in the bending between 'a toy' and 'an electronic gadget'. Its colour and shape should reflect this idea. We believe that this compromise is the most capable of promoting the desired empathy with a broad range of players belonging to different age groups. Furthermore, a deliberately minimalist formal approach would allow the use of the same doll to control several avatars, or its easy transformation through the addition of different icons associated to specific characters on the screen. Thus, we choose a grey, joystick-like design.

Figure 8 shows the design of SenToy as a 3D model, and Fig. 9 shows the model of SenToy with the measures considered.

7.2. The hardware of SenToy and the gesture interpreter

Given the gestures chosen, the hardware of SenToy was designed with a set of sensors connected to a micro controller through a digital or analogical interface. The doll has to have a structure that allows parallel acquisition of external stimulus through the analysis of the values of a set of sensors placed inside it, and at the same time, transmit the results though a wireless communication to the computer. We had to consider, taking into account the specifications of the project and the SenToy's final use that some violent handling may occur. Thus we had to make doll robust, which in turn determined the choice of certain hardware components and the need of a protective box for the processor and accelerometers (see Fig. 10).

The system consists of a central unit with a micro controller (Microchip 16F877). For the transmission of messages between the computer and the doll we decided for radio communication.

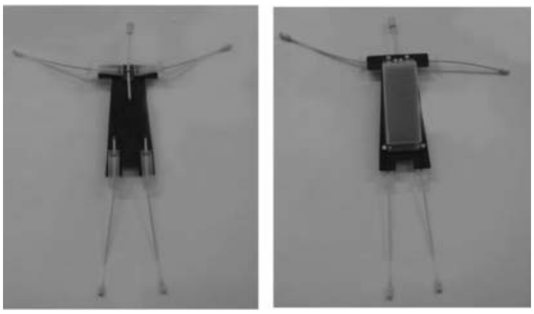

Fig. 10. The protective box of Sentoy.

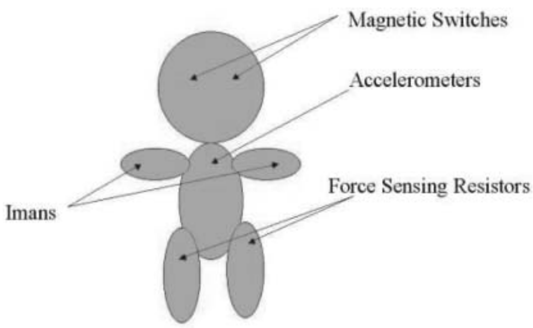

Fig. 11. SenToy 3D model.

The sensors used include two magnetic switches to detect the movement of putting the hands in front of the eyes (see Fig. 11). These sensors work by the proximity of a magnetic field (created by an imam placed in the hands of the toy) closing a switch and establishing a connection between the two terminals. This means that whenever the player places the hands of the toy in front of the eyes that gesture is recognized. To detect walk, Piezoelectric Force Sensing Resistors are used in the legs together with a plastic structure that allows for detecting a bending movement with the legs. Finally, to detect all movements with the torso of the doll, we used accelerometers, which provide a measure of the acceleration in one or two axes. The accelerometers also allow the measure of the vibration of the doll, thus facilitating the distinction between some movements, such as bending, or turn away from the screen. It will allow also for the distinction between rapid and slow movements.

7.3. The SenToy system

Finally, the architecture of the SenToy system is composed of the following components (see Fig. 12):

The Physical Interface (the actual toy) and its acquisition module analyses the interaction between players and SenToy, and infers emotions or actions underlying those gestures. The identification of the gestures is based on a set of rules with certainty values.

The Affective User Model (AUM) is attached to the physical interfaces and is dependent on the application running a virtual world (in this case the FantasyA game) that the synthetic

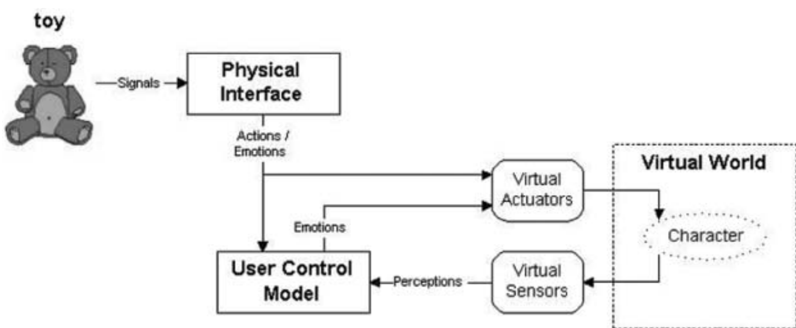

Fig. 12. Architecture of the SenToy system.

characters inhabit. It contains the emotional state ascribed to the synthetic character controlled by the player. It is not really a user model (as described in Hudlicka and McNeese [6]), but rather a module that captures the affective state the player intends the character to have. It is also in the AUM component that the appraisal of the situation (given the game situation) is done, thus affecting also the emotional state of the character.

The physical interface (the doll) transmits a set of signals, generated by its sensors (see Fig 12), resulting from the interaction with the player. The *Stimuli Acquisition module* treats these signals, so they can be easily interpreted and subsequently used to infer the underlying action or emotion.

The virtual world (FantasyA) has a 3D representation of the character controlled by the player, which means that the synthetic character also has perceptions coming from the world it inhabits. Thus, the Affective User Model component receives information from the virtual world it is attached to, the players' goals and other user model data, producing only context dependent emotions (which will be associated to a particular situation in the game).

The SenToy system is now fully implemented according to this outline. We are currently performing user studies of SenToy used for a duel in FantasyA.

8. Discussion and Conclusions

Our initial hypothesis, that it was possible to find a set of behaviours with SenToy to express emotions through gestures, was confirmed, even if some gestures had to be changed to fit better with what most subjects did. The study provided us with valuable design input on: which doll to choose; the orientation of the player; the toy's sensors; which movements and dimensions of movements that worked best; and, finally, which emotions that are most easily implemented in SenToy.

The Wizard of Oz method turned out to be a cost efficient means of getting design input. In total we spent about two weeks on developing the Wizard control and performing the study (though this entails already having access to the Papous avatar).

Finally, instead of a doll, we could of course have allowed the subjects to push the Papous control buttons themselves. However, the idea is that mastering the doll is part of mastering the game. In a game, part of the thrill is in learning how to control the game, be it through a joystick, a mouse, control commands, or, in this case, a doll. The study also showed that players felt that they 'became' the doll thus we achieve the goal of creating a tangible, physical and sympathetic interaction.

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