

Smiling virtual agent in social context

Magalie Ochs¹ · Radoslaw Niewiadomski¹ · Paul Brunet² · Catherine Pelachaud¹

¹*CNRS-LTCl, TélécomParisTech*

{ochs, niewiadomski, pelachaud}@telecom-paristech.fr

²*School of Psychology, Queen's University of Belfast*

p.brunet@qub.ac.uk

Abstract A smile may communicate different communicative intentions depending on subtle characteristics of the facial expression. In this article, we propose an algorithm to determine the morphological and dynamic characteristics of virtual agent's smiles of amusement, politeness, and embarrassment. The algorithm has been defined based on a virtual agent's smiles corpus constructed by users and analyzed with a decision tree classification technique. An evaluation, in different contexts, of the resulting smiles has enabled us to validate the proposed algorithm.

Keywords *Smile · Virtual Agent · Facial*

Expression · Politeness · Amusement · Embarrassment

1. Introduction

A smile is one of the simplest and most easily recognized facial expressions (Ekman and Friesen, 1982). The zygomatic majors, one on either side of the face, are the only two muscles needed to be activated to create a smile. However, a smile may have several meanings – such as amusement, politeness, or embarrassment – depending on subtle differences in the characteristics of the smile itself and of other elements of the face that are displayed with the smile. These different types of smiles are often distinguishable during a social interaction. Recently researchers (Rehm and André, 2005; Niewiadomski and Pelachaud, 2007) has shown that people are also able to distinguish different types of smiles when they are expressed by a virtual agent. Moreover, a smiling virtual agent improves the human-machine interaction, for example enhances the perception of the task and of the agent, and the motivation and enthusiasm of the user (Krumhuber *et al.*, 2008; Theonas *et al.*, 2008). Conversely, an inappropriate smile (an inappropriate type of smile or a smile expressed in an inappropriate situation) may have negative effects on the social interaction (Theonas *et al.*, 2008).

In this paper, we present research that aimed at identifying the morphological and dynamic characteristics of different smiles in a virtual agent. More precisely, we have investigated how a virtual agent may display different a smile in different contexts. For this purpose, we have first analyzed different types of smiles in context-free situations. We created a web application to collect a virtual agent's smile descriptions corpus directly constructed by users. Based on the corpus, we used a machine learning algorithm to determine the characteristics of each type of the smile that a virtual agent may express. As a result, we obtain the algorithm that enables the generation of a variety of facial expressions corresponding to the polite, embarrassed and amused smiles. To validate this algorithm, we have secondly conducted an evaluation to validate the identified smiles in polite, embarrassed, and amused contexts.

The paper structure is as follow. After giving an overview of existing work on humans' smiles (Section 2.1) and on virtual agents' smiles (Section 2.2), we introduce the web application developed to collect the smiles corpus (Section 3). In Section 4, we present the algorithm to compute the smile's characteristics based on the smiles corpus. In Section 5, we present the evaluation, in different contexts, of the smiles resulting from the proposed algorithm. We conclude in Section 6.

2. Related work

2.1 Theoretical background: Types and characteristics of smiles

Unsurprisingly, the most common type of smile is the amused smile, also called felt, Duchenne, enjoyment, or genuine smile. However, when someone smiles, it does not necessarily mean that the person feels happy or amused. Indeed, different types of smiles with different meanings can be displayed and be distinguished by other people. Another type, which is often thought of as the amuse smile's opposite is the polite smile, also called non-Duchenne, false, social, masking, or controlled smile (Frank et al., 1993). Perceptual studies (Frank et al., 1993) have shown that people unconsciously and consciously distinguish between an amused smile and a polite smile. Furthermore, someone may smile in a negative situation. For example, a specific smile appears in the facial expression of embarrassment (Keltner, 1995), or anxiety (Harrigan and O'Connell, 1996).

In the current paper, we focus on the three following smiles: *amused*, *polite* and *embarrassed* smiles. These smiles have been selected because they have been explored in the Human and Social Sciences literature both from the encoder's point of view (i.e., from the point of view of the person who smiles, Keltner, 1995; Ekman and Friesen, 1982) and from the decoder's point of view (i.e., from the point of view of the one who perceived the smile, Ambadar et al., 2009).

The different smiles are distinguishable given their distinct morphological and dynamic characteristics. *Morphological characteristics* include facial movements such as the mouth opening or the cheeks rising. *Dynamic characteristics* correspond to the temporal unfolding of the smile such as the velocity. In the literature on smiles (Ambadar et al., 2009, Keltner, 1995, Ekman and Friesen, 1982), the following characteristics are generally considered to distinguish the amused, polite, and embarrassed smiles¹:

- *morphological characteristics*: AU6 (cheek raising), AU24 (lip press), AU12 (zygomatic major), symmetry of the lip corners, mouth opening, and amplitude of the smile;
- *dynamic characteristics*: duration of the smile and velocity of the onset and offset of the smile.

Concerning the cheek raising, Ekman (2003) claims the orbicularis oculi (which refers to the Action Unit (AU) 6 in the Facial Action Coding System (Ekman et al., 2002)) is activated in an amused smile. Without it, the expression of happiness seems to be insincere (Duchenne, 1862). This finding was also confirmed in the empirical study by Frank et al, (1993) in which participants distinguished between the smiles of "enjoyment" and "non-enjoyment" based on the orbicularis oculi activation. According to Ekman (2003), asymmetry is an indicator of voluntary and non-spontaneous expression, such as the polite smile. Lip press (AU24) is often related to the smile of embarrassment (Keltner, 1995). The different types of smile may have different durations. The felt expressions, such as the amused smile, last from half a second to four seconds, even if the corresponding emotional state is longer (Ekman, 2003). The duration of a polite or embarrassed smile is shorter than 0.5 second or longer than 4 seconds (Ekman and Friesen, 1982; Ekman, 2003). Not only do the overall durations differ, but also the course of the expression varies depending on the type of smiles. The dynamics of facial expressions is commonly defined by three time intervals. The onset corresponds to the interval of time in which the expression reaches its

¹Note that other elements of the face, such as the gaze, the head movements and the eyebrows, influence how a smile is perceived. However, in the presented work, we focus on the influence of the smile and we do not consider the other elements of the face.

maximal intensity starting from the neutral face. Then, the apex is the time during which the expression maintains its maximal intensity. Finally, the offset is the interval of time in which the expression starting from the maximal intensity returns to the neutral expression (Ekman and Friesen, 1982). In the deliberate expressions, the onset is often abrupt or excessively short, the apex is held too long, and the offset can be either more irregular or abrupt and short (Ekman and Friesen, 1982; Hess and Kleck, 1990). Smiles characterized by long onset, long offset, and short apex duration were perceived as significantly more spontaneous and genuine than smiles characterized by short onset, short offset, and long apex duration in the empirical study with the synthesized videos of smiling humans (Krumhuber et al., 2008).

However, no consensus exists on the morphological and dynamic characteristics of the amused, polite, and embarrassed smile. In general, AU6 is more present in amused smile than in polite or embarrassed smile. For instance, according to Ekman the amused smile is characterized by a cheek raising (AU6), the activation of the zygomatic major (AU12) and a symmetry of the zygomatic major. The dynamic characteristics of the amused smile are the smoothness and regularity of the onset, apex, offset and of the overall zygomatic actions, and duration of the smile between 0.5 and 4 seconds (Ekman and Friesen, 1982). The activation of AU6, long onset and offset as well as short apex duration are also indicated in the empirical studies aiming to distinguish enjoyment smiles (Frank et al, 1993; Krumhuber, et al., 2008). Also the results of Ambadar *et al.* (2007) confirm the role of AU6; they indicate the mouth opening as another cue of the smile of enjoyment. The expressions of amusement composed of AUs 6 and 12, accompanied by AU 58 and 63 were correctly recognized (46%) in the forced-choice test including 14 emotions (Keltner and Buswell, 1996). However, recently the role of AU6 in the smile of amusement was challenged by Krumhuber and Manstead (2009).

According to Ekman, in the expression of a polite smile, the cheek raising (AU6) is absent, the amplitude of the zygomatic major (AU12) is small, the smile is slightly asymmetric, the apex is too long, the onset too short, the offset too abrupt, and the lips may be pressed (Ekman and Friesen, 1982).

Finally, according to Keltner (Keltner, 1995; Keltner and Buswell, 1996) a smile of embarrassment is characterized by the lips pressed and by the absence of AU6 that are often accompanied by head and gaze aversion. The expressions of embarrassment composed of AUs 12 and 24 accompanied by AU 51, 54, and 64 were correctly recognized (51%) in the forced-choice test including 14 emotions (Keltner and Buswell, 1996). In Ambadar et al. (2007) work embarrassed/nervous smiles more often characterized by mouth opening and larger amplitude than polite smiles.

2.2 Smiling virtual agents

In order to increase the variability of virtual agent's facial expressions, several researchers have considered different virtual agent's smiles. For instance, in Tanguy (2006), two different types of smiles, amused and polite, are used by a virtual agent. The amused smile is used to reflect an emotional state of happiness whereas a polite smile, called fake smile in Tanguy (2006), is used in a case of a sad virtual agent. The amused smile is represented by lip corners raised, lower eyelids raised, and an open mouth. The polite smile is represented by an asymmetric raising of the lip corners and an expression of sadness in the upper part of the face.

In Rhem and André (2005), virtual agents mask a felt negative emotion of disgust, anger, fear, or sadness with a smile. Two types of facial expression were created according to the Ekman's description (Ekman and Friesen, 1975). The first expression corresponds to a felt emotion of happiness (including an amused smile). The second one corresponds to the other expression (e.g. disgust) masked by unfeeling happiness. In particular, the expression of unfeeling happiness lacks the AU6 activity and is asymmetric (see Section 2.1). It may correspond to a polite smile. A perceptual test has enabled the authors to measure the impact of such fake expressions on the user's subjective impression of the agent. The participants were able to perceive the difference, but they were unable to explain their judgment. The agent expressing an amused smile was perceived

as being more reliable, trustworthy, convincing, credible, and more certain about what it said compared to the agent expressing a negative emotion masked by a polite smile².

In Krumhuber et al. (2008), the authors have explored the impact of varying dynamic characteristics of smile in virtual faces on the user's job interview impressions and decisions. The results show that smiles with long onset and offset durations were associated with 'authentic smiles' (i.e., amused smile). Fake smiles were characterized by short onset and offset durations. The total duration of both types of smiles was equal (4 seconds). During the interaction, the type of smiles used by the virtual agents has an impact on the user's perception: the job is perceived as more positive and suitable in case of authentic smiles. Globally, regardless of its type (e.g., fake or authentic), a smile increases the positive perception of the agent. Niewiadomski and Pelachaud (2007) proposed an algorithm to generate complex facial expressions such as masked or fake expressions. An expression is a composition of eight facial areas, each of which can display signs of emotion. For complex facial expressions, various emotions can be expressed on different areas of the face. In particular, it is possible to generate different expressions of joy; for example a felt expression and a fake one. The felt expression of joy uses the reliable features (e.g., AU6), while the second one is asymmetric.

To create facial expressions of emotions, Grammer and Oberzaucher (2006) performed what they called a reserve engineering approach. They used a 3D facial model driven by FACS (Ekman et al., 2002). A set of facial expressions was rendered randomly. An expression corresponds to either a single Action Unit, a combination of Action Units that were 50% or 100% randomly generated. Participants had to evaluate the expressions along the 3D dimensional space of Pleasure-Arousal-Dominance (Mehrabian and Russell, 1974). Multiple multivariate regression technique was applied enabling the mapping between Action Units and the dimensions Pleasure and Arousal. The authors propose to use the obtained mapping to create facial expressions of emotions.

Several other virtual agents smile during an interaction to either express a positive emotion (Poggi and Pelachaud, 2000) or to create a global friendly atmosphere (Theonas et al., 2008). Generally, these virtual agents use only the amused type of smiles. In this work, we explore different types of smiles a virtual agent may perform. Whereas previous research (presented above) has analyzed the impact of different smiles on the users' perception of the agent or of the interaction, in the work presented in this article, we focus on the different smiles that a user may perceive. More particularly, we have conducted a study to analyze the morphological and dynamic characteristics of the amused, polite, and embarrassed smiles of a virtual agent. In the next section, we present the platform we have developed to study such smiles.

3 E-smiles-creator: Web Application for Smiles Data Collection

In order to identify the morphological and dynamic characteristics of the amused, embarrassed, and polite smile of a virtual agent, we have created a web application, which we have named E-smiles-creator, that enables a user to easily create different smiles on a virtual agent's face. The interface of the E-smiles-creator is composed of 4 parts (Figure 1).

²Several other works have explored the impact of a virtual agent's expressions of emotion on user's perception (for a detailed review on this subject, see Beale and Creed, 2009). In this article, we focus primarily on studies that have compared the user's perception of different virtual agent's smiles.

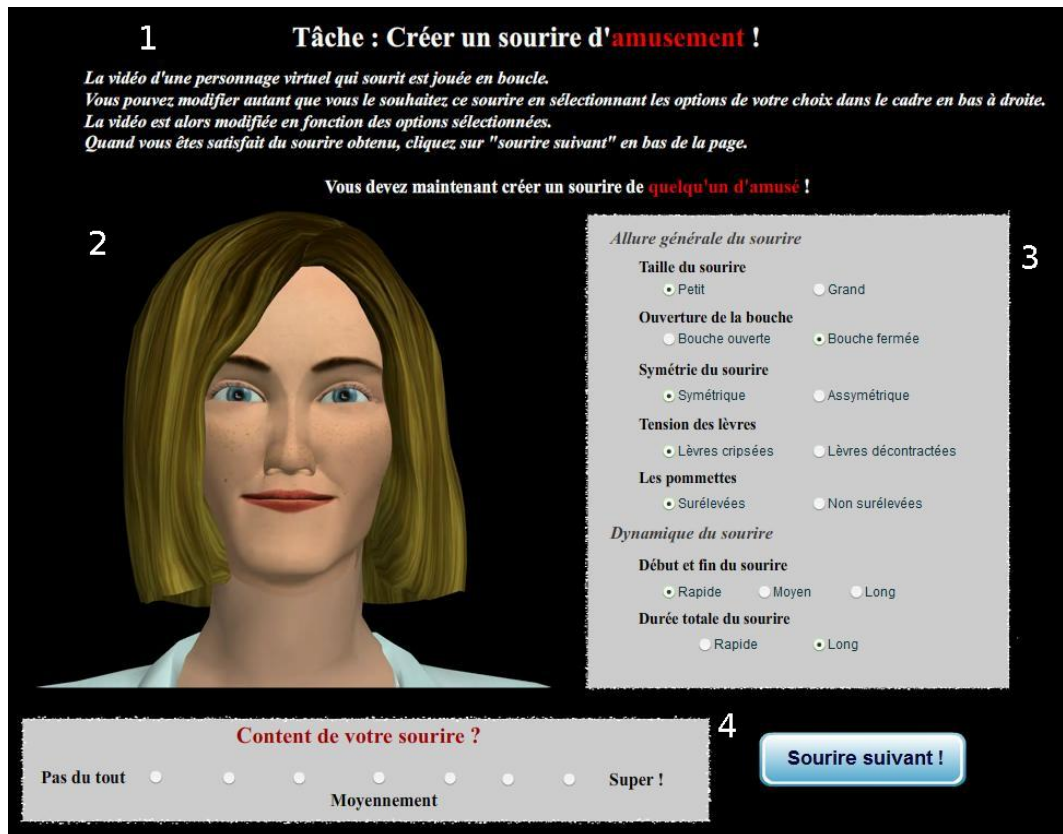


Figure 1: The figure is a screenshot of the *E-smiles-creator*. In section 1, at the top is a description of the task: the smile that the user has to create (e.g., an amused smile). In section 2, on the left side, a video is showing, in loop, the virtual agent animation. In section 3, on the right side is a panel with different smile parameters (e.g., the duration) that the user may change to create the smile (the video on the left changes accordingly). In section 4, at the bottom is a Likert scale that enables the user to indicate his level of satisfaction with the smile created.

Using the *E-smiles-creator*, the user can generate any smile by choosing a combination of the seven parameters. When the user changes the value of one of the parameters, a corresponding video is automatically played. Based on the research of human smiles (see Section 2.1), we consider the following morphological and dynamic characteristics of a smile: 1) the amplitude of the smile, 2) the mouth opening, 3) the symmetry of the lip corners, 4) lip press, 5) cheek raising, 6) the duration of the smile, and 7) the velocity of the onset and the offset of the smile. Accordingly, on the right side of the *E-smiles-creator* interface (Figure 1, panel 3), the user may select these parameters of the smile. We have considered two or three discrete values for each of these parameters: 1) small or large smile (for the amplitude); 2) open or close mouth; 3) symmetric or asymmetric smile; 4) pressed or relaxed lips; 5) cheek raised or not raised; 6) short (1.6 seconds) or long (3 seconds) total duration of the smile, and 7) short (0.1 seconds), average (0.4 seconds) or long (0.8 seconds) beginning and end of the smile (for the onset and offset)³. Considering all the possible combinations of these discrete values, we have created 192 different videos of smiling agent. An example of a sequence of images of a video of the virtual agent smiling is illustrated Figure 2.

Note that our method to create facial expressions differs from existing approaches in several ways. Commonly, expressions are first created by researchers (possibly randomly) and then participants rate them (such as in (Grammer *et al.*, 2006)). In the proposed method, we did the way around. That is, we selected a set of key features found in the literature and we ask participants to create the expression they believe corresponds to a given emotion. Our approach allows participants to mould an expression by determining which facial features to activate with which intensities. In this way they could see all possible combinations before making a choice. The mapping between

³The values of the onset and the offset have been defined to be consistent with the values of the duration of the smile. Moreover, as a first step, discrete variables have been considered. To obtain a more fine-grained description of smiles, continuous variables could be considered.

communicative and emotional functions and facial actions is not solely obtain through perceptual studies but also by asking participants to actively create what they believe to be the plausible expressions.



Figure 2: Example of a sequence of the first images of a video of the smiling virtual agent

The *E-smiles-creator* was created using Flash technology to enable diffusion on the web. The interface of the *E-smiles-creator* is in French. The user was instructed to create one animation for each type of smile. For each smile created, the user was instructed to rate his level of satisfaction concerning the smile created. The order of smiles to be illustrated and the initial values of the seven parameters are chosen randomly.

The participants (N= 348, 195 females) had a mean age of 30 years and were mainly French. Given that each participant created one smile for each of the three categories, we collected 1044 smile descriptions: 348 descriptions for each smile (amused, polite, and embarrassed). On average, the participants were satisfied with the created smiles (5.28 on a Likert scale of 7 points)⁴.

Globally, the amused smiles created by the participants are mainly characterized by large amplitude, an open mouth, and relaxed lips. Most of them also contain the activation of the cheek raising, and a long global duration. Compared to the amused smiles, the embarrassed smiles often have small amplitude, a closed mouth, and pressed lips. They are also characterized by the absence of cheek raising. The polite smiles are mainly characterized by small amplitude, a closed mouth, symmetry, relaxed lips, and an absence of cheek raising (for more details on the corpus of smiles, see Ochs et al., 2010).

Based on this smiles corpus and on a decision tree classification technique, in the next section, we present an algorithm to determine the morphological and dynamic characteristics of the smile types that a virtual agent may express.

4 Smiles Decision Tree Learning

We propose an algorithm to generate different types of smile in virtual agent. It allows an agent to display various polite, amused or embarrassed smiles. Because it is important that virtual agents show variability in its behaviors (Wang *et al.*, 2008), we aim at allowing our agent to choose among several possible smiles to express its communicative intentions. Our approach is based on machine learning methodology and on the smiles corpus collected using *E-smiles-creator* (see Section 3).

4.1 The decision tree

In order to analyze the smiles corpus, we have used a *decision tree learning algorithm* to identify the different morphological and dynamic characteristics of the amused, polite, and embarrassed

⁴In more detail, the user's satisfaction is the same for the three smiles (between 5.2 and 5.5)

smiles of the corpus. The input variables (predictive variables) are the morphological and dynamic characteristics and the target variables are the smile types (amused, embarrassed, or polite). Consequently, the *nodes* of the decision tree correspond to the smile characteristics and the *leaves* are the smile types. Then walking on the tree from the root to the leaves corresponds to different smile patterns. We have chosen the decision tree learning because this technique has the advantage to be well-adapted to qualitative data and to produce results that are interpretable and that be easily implemented in a virtual agent.

To create the decision tree, we took into account the level of satisfaction indicated by the user for each created smile (a level that varied between 1 and 7). More precisely, in order to give a higher weight to the smiles with a high level of satisfaction, we have done *oversampling*: each created smile has been duplicated n times, where n is the level of satisfaction associated with this smile. So, a smile with a level of satisfaction of 7 is duplicated 7 times whereas a smile with a level of satisfaction of 1 is not duplicated. The resulting data set is composed of 5517 descriptions of smiles: 2057 amused smiles, 1675 polite smiles, and 1785 embarrassed smiles.

To construct the decision tree, we have used the free data mining software TANAGRA (Rakotomalala, 2005) that proposes several data mining methods for data analysis. We have used the CART (Classification And Regression Tree) method (Breiman et al., 1984), a popular and powerful method to induce decision tree. The resulting decision tree is represented in Figure 3. We have set a minimum size of node to split of 75 to avoid a large number of leaves and then an uninterpretable tree. The resulting decision tree is composed of 39 nodes and 20 leaves. The values within parentheses at each leaf correspond to the percentage of well-classified smiles in this category and the total smiles that fall within this category. For example, for the leaf indicated by a black arrow Figure 3, 101 smiles correspond to an open mouth of a small size with lip pressed and short smile duration; and 61% of these 101 smiles are classified as polite. All the input variables (the smile characteristics) are used to classify the smiles.

To compute the error rate, a 10-fold cross-validation (with 5 trials) has been performed. The global error rate is 27.75%, with a 95% confidence interval of 1.2%: the global error rate is in the interval [26.55%, 28.95%]. An analysis of the error rate for each smile type shows that the amused smiles are better classified (18 % of error with a confidence interval of 1.8%) than the polite (34% of error with a confidence interval of 1.7%) and the embarrassed smiles (31% of error with a confidence interval of 1.7%). Indeed, the confusion matrix reveals that the polite and embarrassed smiles are often confused with each other compared to the amused smiles. In the next section, we discuss in more details how the resulting decision tree can be used to identify the smiles that a virtual agent may express.

4.2 Smile selection based on decision tree

Our smiles decision tree reveals 20 different smile patterns, corresponding to the 20 leaves of the tree. Ten leaves are labeled as polite smiles, 7 as amused smiles, and 3 as embarrassed smiles. The nodes of the tree inform us of the relevancy of the morphological and dynamic characteristics to distinguish the different types of smile. The nodes close to the root of the tree are more relevant than those close to the leaves. For example, the structure of the tree reveals that the most relevant parameter to distinguish smiles is the opening of the mouth whereas the duration of the onset and offset does not appear to be relevant to distinguish embarrassed smiles from other smiles (Figure 3).

Because some branches of the tree do not contain a value for each morphological and dynamic characteristic, more than 20 smiles may be created from our decision tree. For instance, for the first polite smile pattern that appears in the tree (indicated by a black arrow on Figure 3), the size of the smile, its duration, and the velocity of the onset and offset are not specified. Consequently, this polite smile pattern can be expressed by the virtual agent in 12 different manners.

In order to identify the smile that the virtual agent should express, we propose an algorithm based on the resulting decision tree. We suppose that as input of the algorithm we have the type of smile the virtual agent should express (amused, polite, or embarrassed) and a value, between 0 and 1, called confidence level. This value expresses both the importance of the smile as well-recognized by the user, and the variability of smiles that the virtual agent could express. The closer the value is to 1 (resp. 0), the more it is important (resp. it is not important) that the smile is recognized by

the user as embarrassed, amused, or polite. But, at the same time, the variability is lower. Indeed, a high value implies few possible smiles to express whereas an average value enables the virtual agent to express several different smiles. For example, an input of the algorithm (polite; 0, 9) means that the virtual agent has to express a polite smile and it is important that this smile is perceived as polite by the user. However, an input (polite; 0, 6) gives more polite smile variability. The algorithm to determine the virtual agent's smile is composed of two steps: a first step aims at selecting the smile pattern in the tree, and the second step determines the smile from the pattern.

In the first step of the algorithm, the confidence level is used to select the appropriate smile pattern in the decision tree. More precisely, for each leaf of the tree, we compute the 95% confidence interval from the classification rate and the number of examples in the leaf (Figure 3) using the formula:

$$r = 1.96 * \sqrt{\frac{(1 - p)}{N}}$$

such as N is the number of examples and p the classification rate. The 95% confidence interval is then $[p-r, p+r]$. For instance, for the first polite smile appearing in the tree (indicated by a black arrow on Figure 3), 60.41% of 101 examples of smile with these characteristics are well-classified (Figure 3). The 95% confidence interval for this leaf is $[60.41-9.5, 60.41+9.5]$. The confidence interval enables us to consider the number of examples in the classification rate. Finally, the selected smile pattern will be the one with the specified type and with the smallest confidence interval containing, or the closest to, the confidence level value. For instance, the selected smile pattern for a polite smile with a confidence level of 0.9 will be the fifth polite smile that appears in the tree (with the classification rate 84.05% on 370 examples, so, the 95% confidence interval $[80.32; 87.79]$): a symmetric smile with a closed mouth, relaxed lips, and without cheeks raised.

In the second step of the algorithm, in order to determine the smile's characteristics not defined in the tree, we consider the contingency table representing the frequency of smile types for each characteristic (Table 1). For example, 16.4% of the total amused smiles (2057), 73.1% of the total embarrassed smiles (1785), and 67.7% of the total polite smiles (1675) have a small size.

For example, if the selected smile pattern is the first polite smile that appears in the tree (indicated by a black arrow on Figure 3), the following characteristics are not specified in the tree: the smile symmetry, the cheek raising, and the velocity of the onset and offset. Because in the contingency table, it appears that a majority of polite smiles is characterized by a symmetry, absence of cheek raising, and an average velocity of the onset and offset, we consider a smile with such characteristics and the characteristics described in the branch of the tree leading to the selected smile.

Finally, the proposed algorithm enables one to determine the morphological and dynamic characteristics of the smile that a virtual agent should express given the type of smile and the importance that the user recognizes the expressed smile. The advantage of such a method is to consider, not only one amused, embarrassed, or polite smile but several smile types. That enables one to increase the variability of the virtual agent's expressions. Compared to the literature on human smiles (Ekman and Friesen, 1982; Keltner, 1995; Ambadar et al., 2009), the decision tree contains the typical amused, polite, and embarrassed smiles as reported in the literature (see Section 2.1). However, it contains also amused, polite, and embarrassed smiles with other morphological and dynamic characteristics. In order to evaluate the proposed algorithm, we have performed an evaluation of the resulting smiles that we present in the next section.

Decision tree

- MOUTH_OPEN in [open]
 - SMILE_SIZE in [small]
 - LIPS_PRESS in [no]
 - SMILE_DURATION in [short] then SMILE_TYPE = polite (60,40 % of 101 examples) ←
 - SMILE_DURATION in [long]
 - SMILE_SYM in [sym]
 - CHEEK_RAISING in [no] then SMILE_TYPE = polite (66,00 % of 50 examples)
 - CHEEK_RAISING in [yes] then SMILE_TYPE = amused (64,58 % of 48 examples)
 - SMILE_SYM in [asym] then SMILE_TYPE = amused (60,53 % of 76 examples)
 - LIPS_PRESS in [yes]
 - SMILE_SYM in [sym] then SMILE_TYPE = polite (61,11 % of 54 examples)
 - SMILE_SYM in [asym] then SMILE_TYPE = embarrassed (69,09 % of 55 examples)
 - SMILE_SIZE in [large]
 - LIPS_PRESS in [no]
 - SMILE_DURATION in [short]
 - CHEEK_RAISING in [no] then SMILE_TYPE = polite (52,63 % of 57 examples)
 - CHEEK_RAISING in [yes] then SMILE_TYPE = amused (73,08 % of 130 examples)
 - SMILE_DURATION in [long] then SMILE_TYPE = amused (89,38 % of 951 examples)
 - LIPS_PRESS in [yes]
 - SMILE_ONOFFSET in [short,medium] then SMILE_TYPE = amused (41,67 % of 34 examples)
 - SMILE_ONOFFSET in [long] then SMILE_TYPE = embarrassed (61,29 % of 31 examples)
- MOUTH_OPEN in [close]
 - LIPS_PRESS in [no]
 - SMILE_SYM in [sym]
 - CHEEK_RAISING in [no] then SMILE_TYPE = polite (84,05 % of 370 examples)
 - CHEEK_RAISING in [yes]
 - SMILE_SIZE in [small] then SMILE_TYPE = polite (66,12 % of 121 examples)
 - SMILE_SIZE in [large]
 - SMILE_ONOFFSET in [short,medium] then SMILE_TYPE = amused (45,00 % of 36 examples)
 - SMILE_ONOFFSET in [long] then SMILE_TYPE = polite (67,27 % of 55 examples)
 - SMILE_SYM in [asym]
 - SMILE_DURATION in [short] then SMILE_TYPE = polite (61,84 % of 152 examples)
 - SMILE_DURATION in [long]
 - SMILE_SIZE in [small] then SMILE_TYPE = polite (53,72 % of 121 examples)
 - SMILE_SIZE in [large]
 - CHEEK_RAISING in [no] then SMILE_TYPE = amused (57,41 % of 54 examples)
 - CHEEK_RAISING in [yes] then SMILE_TYPE = polite (41,46 % of 41 examples)
 - LIPS_PRESS in [yes] then SMILE_TYPE = embarrassed (70,60 % of 1085 examples)

Figure 3: Smiles Decision Tree

5 Evaluation of Smiles in Contexts

Many researchers agree that context is important in the perception of emotional displays (e.g., Fernandez-Dols and Ruiz-Belda, 1995). We decided to evaluate our smile expressions in three different contexts. While in previous experiments the focus was more on the effect of smiles on the subjective impression of a virtual agent or a task (for example, in Rhem and André, 2005; Krumhuber et al., 2008), we aim at verifying if the smiles, selected by our algorithm, are perceived by the user as appropriate in amusement, polite, and embarrassed contexts. For example, a smile generated by the algorithm as a polite one should be considered by the users to be more appropriate in a polite context. Our hypothesis is the following:

Hypothesis. Each specific smile should be rated as more appropriate in the corresponding scenario than the other types of scenarios. For example, the polite smile with the id 1 (Table 2) should be rated as higher in appropriateness in a polite scenario compared to an amused or an embarrassed scenario.

A validation of this hypothesis will enable us to validate our algorithm (i.e. the dynamic and morphological characteristics of the different types of smile generated by our algorithm). We present in the next section the method used to test this hypothesis.

variable	value	amused	embarrassed	polite
size	small	16,40%	73,10%	67,70%
	big	83,60%	26,90%	32,30%
mouth	close	14,40%	81,8%	76%
	open	85,60%	18,20%	24%
symmetry	symmetric	59,90%	40,50%	67,10%
	asymmetric	40,40%	59,10%	32,90%
lip press	pressed	92,2%	25,4%	69,4%
	non pressed	7,8%	74,6%	30,6%
cheek raising	no	21,6%	59%	58,9%
	yes	78,4%	41%	41,1%
onset/offset	short	33,4%	28,9%	30,3%
	average	30,3%	39,6%	37,1%
	long	36,3%	31,50%	32,6%
duration	short	15,6%	43,6%	42,9%
	long	84,4%	56,4%	57,1%

Table 1: Contingency table of the smile's characteristics and the smile types

5.1 Method

Participants. Seventy-five individuals participated in this evaluation (57 female) with a mean age of 32 (SD = 11.84). They were recruited via mailing lists online. The participants were predominantly from France (N = 62), followed by Canada (N = 7) and the United Kingdom (N = 2). There was one participant from Germany, Algeria, and Italy respectively.

Procedure. In order to verify the hypothesis, we performed the evaluation on the web through a platform of test developed using Flash technology. The test has two parts. In the first part, six scenarios (among twelve) were presented to the user. For each scenario, three video clips of virtual agent's different smiles were presented (Figure 4). We asked to the user to imagine Greta displaying the facial expression while she was in the situation presented in the scenario. The user had to rate each of the three facial expressions on its appropriateness for the given scenario on a 7 point Likert scale and to rank the three clips in order of appropriateness.

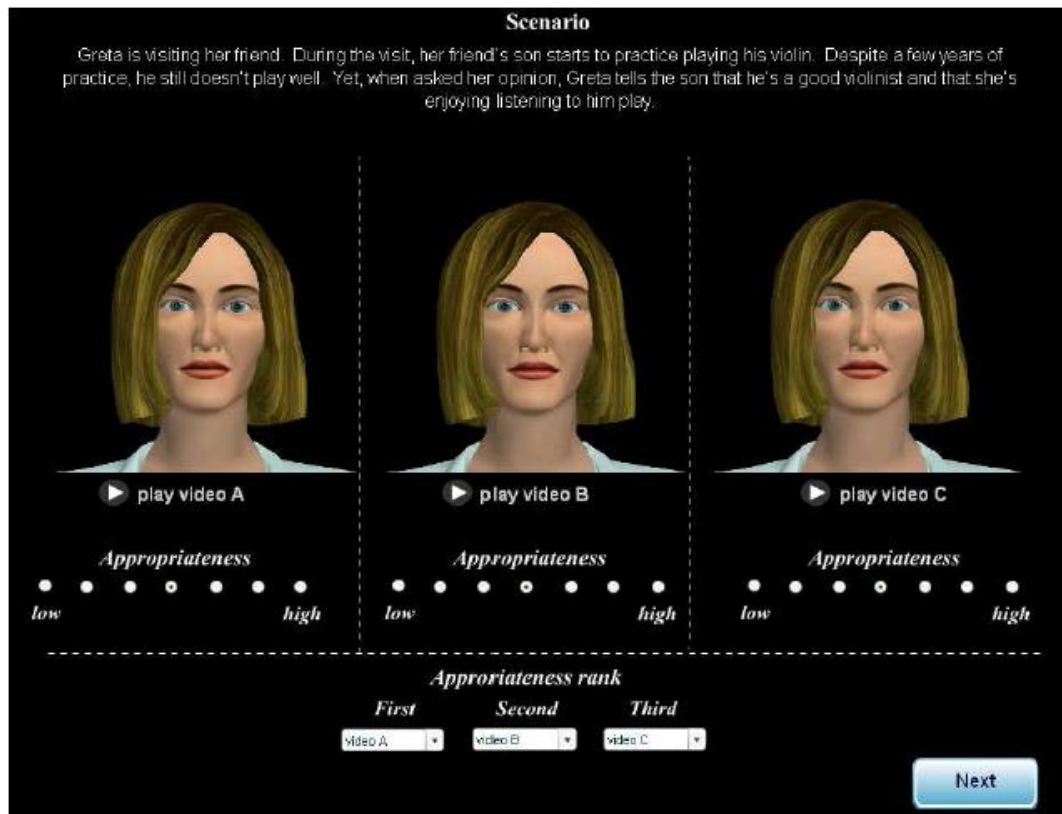


Figure 4: Screenshot of the first part of the test

To try to ensure that the user watched each video clips, we imposed that the user cannot go to the next page before clicking on the play button of each clip. The order of the scenarios and of the video clips has been counterbalanced to avoid an effect of the order on the results. In total the duration of the test was around 20 minutes.

In the second part of the test, the same six scenarios were presented to the user. For each scenario, we asked to the user to rate it on three dimensions: embarrassment, amusement, and politeness (Figure 5). In this way, we again verify if the scenario is perceived by the users as expected. Once again, the order of the presented scenario was counterbalanced to avoid an effect of the order on the results.

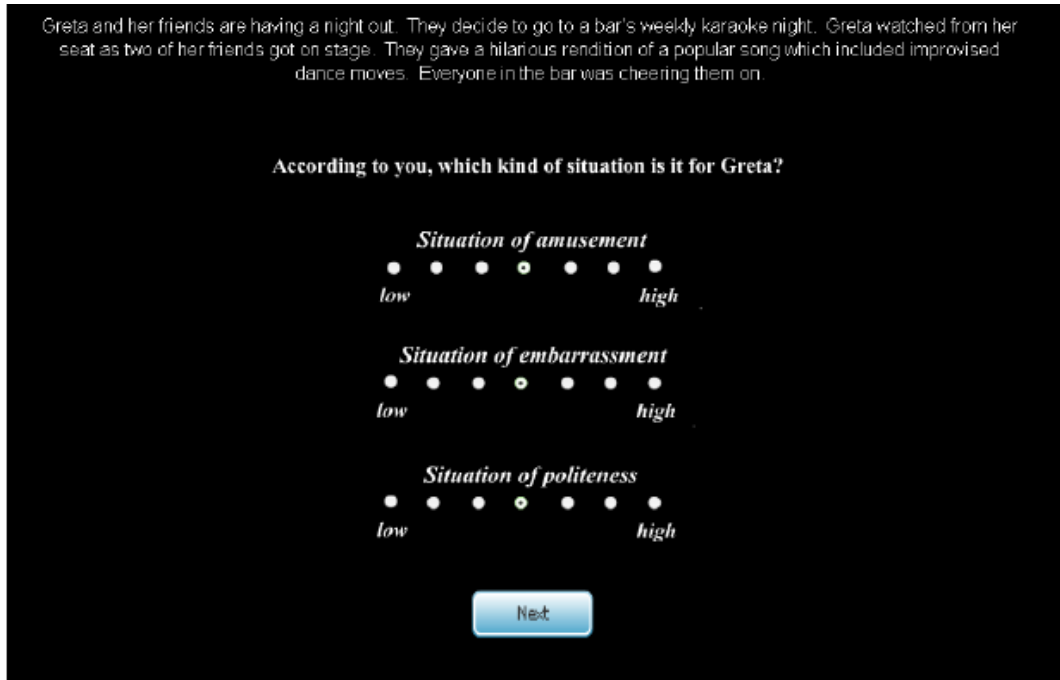


Figure 5: Screenshot of the second part of the test

Smiles. The video clips presented to the user correspond to the smiles resulting from our algorithm (Section 4). For each type, we used the four different smiles with the highest confidence level. The selected smiles are presented Table 2. In more details, for amusement and politeness, we used the four highest confidence smile patterns while the remaining cues were chosen according to the procedure described in Section 4. For embarrassment, only three different patterns exist in the tree. The fourth smile was generated using the same smile pattern as the third one, while the remaining three cues were chosen to be opposite to the ones indicated by the contingency table.

id	type	size	mouth	symmetry	Lip press	cheek raising	Onset offset	duration
1	polite	small	close	yes	no	no	0.4s	3s
2	Polite	large	close	yes	no	yes	0.8s	3s
3	Polite	small	close	yes	no	yes	0.4s	3s
4	Polite	small	close	no	no	no	0.4s	1.6s
5	amused	large	open	yes	no	yes	0.8s	3s
6	Amused	large	open	yes	no	yes	0.8s	1.6s
7	Amused	small	open	yes	no	yes	0.8s	3s
8	Amused	small	open	no	no	yes	0.8s	3s
9	Embarass.	small	open	no	yes	no	0.4s	3s
10	Embarass.	small	close	no	yes	no	0.4s	3s
11	Embarass.	small	close	no	yes	no	0.1s	3s
12	Embarass.	large	open	no	yes	no	0.8s	3s

Table 2: The characteristics of the selected smiles for the evaluation

Scenarios. To evaluate the appropriateness of smiles in different contexts, we have developed and selected twelve scenarios. Each scenario presented a woman named Greta involved in a particular situation and activity. The scenarios were 3-4 sentences long.

The *embarrassment scenarios* were adapted from scenarios developed by Sabini, Siepmann, Stein and Meyerowitz (2000). An example scenario is “Greta was attending a magic show with some friends. It was a packed auditorium, but they were sitting at the front, close to the stage. The magician said she needed an assistant from the audience for her next trick. She called on Greta to come up on stage and help.”

The *politeness* and *amusement* scenarios were developed to match the embarrassment scenarios in length and style. An example of the politeness scenarios is “Greta was a hosting a party at her home. The guest list included many people who didn’t know one another. As her guests began to arrive, Greta would greet them at the door and take their coats. Before moving on to other guests, she would offer them a drink and introduced them to other guests present.” And an example of the amusement scenarios is, “Greta and her friends are having a night out. They decide to go to a bar’s weekly karaoke night. Greta watched from her seat as two of her friends got on stage. They gave a hilarious rendition of a popular song which included improvised dance moves. Everyone in the bar was cheering them on”.

To ensure that the scenarios reliably represented the intended states, we ran a pre-test to evaluate them. Scenarios were pre-tested with a different sample of participants (N=10). These participants were asked to assign a label of polite, amused, or embarrassed to the scenarios. From their answers, we chose 4 scenarios (2 of each subcategory) labeled by at least 8 of the participants as polite, as amused, or as embarrassed. The scenarios with less agreement among the participants were eliminated from consideration. Additionally, as a secondary check of the scenarios, we used the responses from the second part of the main experiment. Participants were asked to rate the scenarios on politeness, amusement, and embarrassment (without any smile stimuli). A repeated measures ANOVA was conducted with each scenario to compare its politeness, amused, and embarrassed ratings. The analysis revealed that for each of the 12 scenarios, there was a statistically significant main effect of states (p 's < .001). Main effect comparisons determined that in each of the 12 scenarios, the intended state was rated statistically significantly higher than the two other states (p 's < .001). Given the results of the pre-test and of the second part of the main experiment, we are confident that the scenarios properly represent the intended state.

In the next section, we present the results of the evaluation.

5.2 Results

For a first pass, analyses were run to include sex of participants as a factor. However, no interaction or main effect of sex was found. Consequently, we have collapsed the groups and do not include sex in the reported analyses.

Comparison of each smile across types of scenarios. Repeated measures ANOVAs was conducted to compare the ratings of appropriateness of each smiles across the three types of scenarios. Smiles are numbered 1 through 12 (as labeled in Table 2). The mean ratings of appropriateness (and standard errors) of each smile in the politeness, amusement, and embarrassment scenarios respectively are presented in Table 3.

The first four smiles are the polite smiles. For *Smile 1*, the analyses revealed a significant main effect of type of scenario, $F(1, 2) = 9.6$, $p = .00$. Pairwise comparisons demonstrated that Smile 1 was rated significantly more appropriate in a politeness scenario than in an amusement scenario ($p = .00$) or embarrassment ($p = .004$). For *Smile 2*, the analyses revealed a significant main effect of type of scenario, $F(1,2) = 9.17$, $p = .00$. Smile 2 was statistically significantly rated higher in the amused scenario compared to the embarrassed and polite smile (p 's < .001). For *Smile 3*, the analyses revealed a significant main effect of type of scenario, $F(1,2) = 26.11$, $p = .00$. Smile 3 was statistically significantly rated higher in the polite scenario compared to the amused scenario ($p < .001$), but not statistically significantly rated higher compared to the embarrassed scenario ($p = .23$). For *Smile 4*, the analyses revealed a significant main effect of type of scenario, $F(1,2) = 20.92$, $p = .00$. Smile 4 was statistically significantly rated as more appropriate in the polite scenario compared to the amused or embarrassed scenarios (p 's < .01).

For all 4 amused smiles, the analyses revealed a significant main effect of the type of scenario. *Smile 5* [$F(1,2) = 50.33$, $p = .00$] and *Smile 6* [$F(1,2) = 20.63$, $p = .00$] were both statistically significantly rated as more appropriate in the amused scenario compared to the polite or

embarrassed scenarios (p 's $< .02$). *Smile 7* [$F(1,2) = 48.85, p = .00$] was statistically significantly rated higher in the amused scenario compared to the embarrassed scenario ($p < .001$), but not statistically significantly rated higher compared to the polite scenario ($p = .18$). *Smile 8* [$F(1,2) = 28.75, p = .00$] was statistically significantly rated more appropriate in the amused scenario compared to the polite scenario ($p < .001$), and nearly statistically significantly rated higher than compared to the embarrassed scenario ($p = .08$).

For all 4 *embarrassed smiles*, the analyses revealed a significant main effect of the type of scenario. However, follow up analyses determined that smiles were not rated more appropriate in the embarrassed scenarios. For *Smile 9* [$F(1,2) = 7.67, p = .001$], the ratings of appropriateness in the embarrassed scenario was statistically significantly higher than in the polite scenario ($p < .001$), but not compared to the amused scenario ($p = .86$). For *Smiles 10* [$F(1,2) = 106.20, p = .00$] and *11* [$F(1,2) = 46.54, p = .00$], the ratings of appropriateness were statistically significantly higher in the embarrassed scenarios compared to the amused scenarios (p 's $< .001$), but not statistically significantly higher compared to the ratings in the polite scenario (p 's $> .11$). Finally, *Smile 12* [$F(1,2) = 14.36, p = .00$] was statistically significantly rated higher in the amused scenario compared to the embarrassed scenario ($p < .001$).

id	Politeness	Amusement	Embarrassment
1	4.74 (1.45)	3.75 (1.51)	3.93 (1.64)
2	3.35 (1.75)	4.41 (1.82)	3.49 (1.83)
3	5.06 (1.49)	3.43 (1.52)	4.81 (1.50)
4	4.48 (1.79)	2.83 (1.75)	3.74 (1.84)
5	3.56 (1.80)	6.01 (1.12)	3.70 (1.98)
6	3.14 (1.75)	4.73 (1.68)	4.15 (1.73)
7	5.23 (1.48)	4.93 (1.62)	2.95 (1.65)
8	2.75 (1.42)	4.53 (1.61)	4.04 (1.78)
9	3.30 (1.43)	4.23 (1.78)	4.29 (1.98)
10	5.26 (1.82)	2.06 (1.51)	4.91 (1.60)
11	4.56 (1.93)	2.28 (1.59)	4.71 (1.84)
12	3.91 (1.89)	5.15 (1.65)	4.24 (1.75)

Table 3: Mean (and standard deviations in parentheses) ratings of appropriateness of each smile in politeness scenarios, amusement scenarios, and embarrassment scenarios. Smile numbering matches labels presented in Table 2

Comparison of smiles within the corresponding category. An ANOVA was conducted for each category comparing the scores of appropriateness of the 4 smiles in the corresponding scenarios (e.g. the appropriate ratings in the polite scenarios of the 4 polite smiles) (see Figure 5 for means and standard errors). For the polite category, the analysis revealed a statistically significant main effect, $F(1,3) = 15.78, p < .001$. *Smile 2* was statistically significantly rated the lowest compared to other 3 polite smiles (p 's $< .001$). The highest rated polite smile was *smile 3*, followed by *smile 1* and *smile 4*.

For the category of amused smiles in the amused scenarios, the analysis revealed a statistically significant main effect $F(1,3) = 12.45, p < .001$. *Smile 5* was rated statistically more appropriate compared to *smile 6*, *smile 7*, and *smile 8*.

Finally, for the category of embarrassed smiles in the embarrassed scenarios, the analysis revealed a statistically significant main effect $F(1,3) = 2.88, p = .036$. *Smile 10* was statistically significantly rated as higher in appropriateness in the embarrassed scenarios (p 's $< .02$) compared to *Smile 9* and *Smile 12*. *Smile 11* was not statistically significantly lower than *smile 10* nor statistically significantly rated higher than *smiles 9* and *12*.

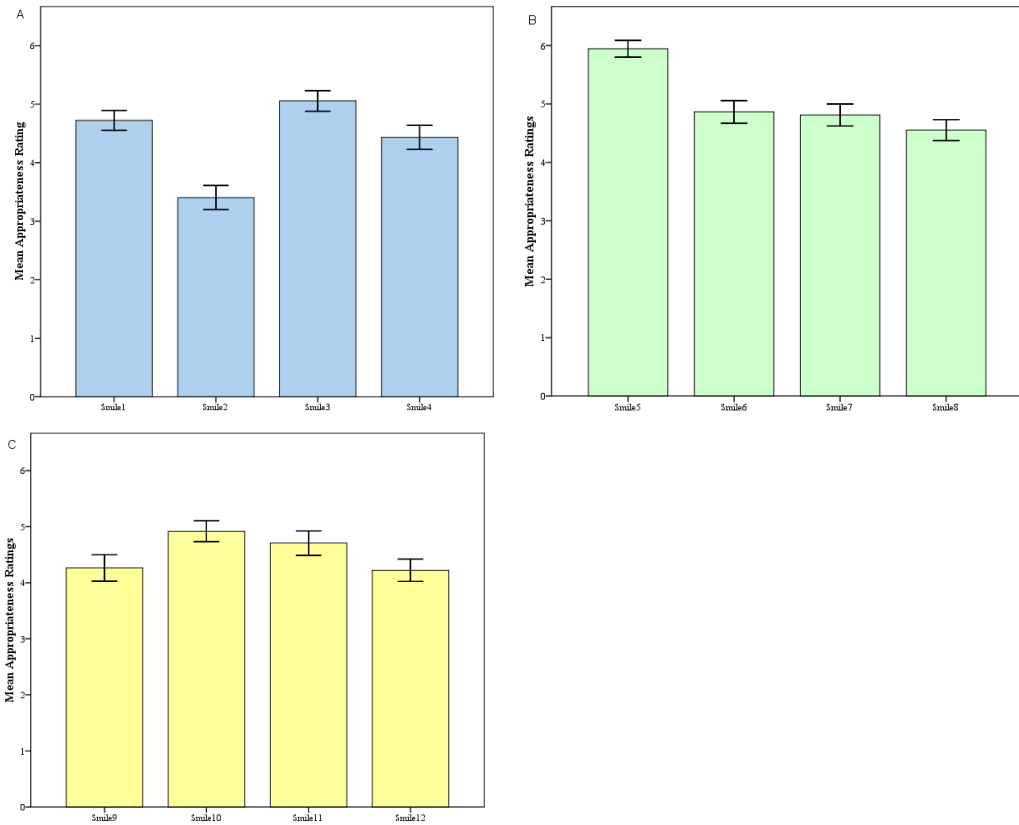


Figure 4: Comparison of smiles within corresponding category. The error bars represent 1 standard error. A. The mean ratings of appropriateness of the four ‘polite’ smiles when shown within a polite context. B. The mean ratings of appropriateness of the four ‘amusement’ smiles when shown within an amused context. C. The mean ratings of appropriateness of the four ‘embarrassed’ smiles when shown within a embarrassed context.

5.3 Discussion

In this experiment, the goal was to determine if our smile generation algorithm (see Section 4) creates appropriate facial expressions for three different types of smiles. The results generally confirmed our hypothesis. Indeed, 10 out of 12 smiles were ranked significantly higher in their corresponding context compared to at least one of two alternate context types. In more detail, 4 smiles (id: 1, 4, 5, 6) received a significantly higher score in the corresponding context compared to the other 2 contexts, while other six smiles (id: 3, 7, 8, 9, 10, 11) were ranked significantly higher compared to one different context. Only 2 out of 12 smiles, the results showed that these smiles may do not match the intended context. One of them, the smile 12, corresponds to the last embarrassed smile pattern that has relatively high error rate (see Section 5.1). Thus, it is reasonable that this signal was often differently interpreted. In the case of smile 2, participants rated it higher in amusement scenarios than in the politeness scenarios. On the other hand, smile 2 was generated from a second polite smile pattern. If we compare this smile with three other polite smiles (see Table 2), we can notice that smile 2 differs from other polite smiles on the intensity variable (only smile 2 between all polite smiles has a large intensity). It is also the only one polite smile that has a medium duration of onset/offset. Then in Table 1, we can see that polite smiles in our corpus were much more often characterized by small intensity (67% vs. 32%). At the same time the percentage rates for three different possible durations were similar (30.3%, 37.1% and 32.6%). It leads us to believe that the large intensity of smile 2 resulted in the participants interpreting it differently than the other polite smiles.

It is important to notice that the smiles generated with our algorithm are fairly consistent with the studies concerning human smiling (see Section 2.1). The lip press occurs only in embarrassment smiles which is consistent with Keltner's findings (e.g. Keltner and Buswell, 1997). The cheek raising mainly occurs in amusement smiles (all four cases) while it occurs only in two others smiles (see Ambadar et al., 2007). The mouth opening occurs in all amusement smiles, but it also occurs more often in embarrassed smiles than in polite smiles (see Ambadar et al., 2007). Amusement smiles are also more often symmetric (3 out of 4 cases) than other smiles. Finally the amusement smiles have often longer onset/offset than other smiles which is consistent with findings by Krumhuber et al. (2008). It would suggest that users apply what they know about human smiles to virtual agents.

6 Conclusion

In this work we proposed an algorithm that allows our agent to generate different smiles, from a library of smiles, to communicate three different communicative intentions: embarrassment, politeness, and amusement. For this purpose, firstly we asked participants to create different smiles by combining seven visual cues of the virtual agent face. Then we proposed an algorithm that gives our agent the opportunity to display these various smiles to communicate its intentions. Last but not least we evaluated the smiles in three different contexts. The evaluation results confirmed that our algorithm generate appropriate smiles.

Despite the positive results, there are a few limitations of the proposed approach that should be highlighted. First, only some characteristics of the face have been considered. Others characteristics, such as the head movement or gaze direction, influence the perception of a smile. Other research (Niewiadomski et al., 2009) has explored how multimodal non-verbal behaviors can express emotions. However, note that one objective of the presented research is precisely to analyze if the considered parameters are sufficient to distinguish different types of smile. The results show that the presented morphological and dynamic characteristics can be used to generate different types of smiles, and are successful at representing different intentions. However, the combination of these parameters with other element (e.g., head movements) can modify the perception of the smile. Moreover, the different discrete values of the chosen morphological and dynamic characteristics (e.g., the intensity of the asymmetry) have been defined arbitrarily. Consequently, a logical next step in the development of virtual agent smiling is to consider additional parameters, values, and elements, which could lead to another decision tree.

In the presented study, we have considered three meanings (i.e. polite, amused, and embarrassed) of smiles and we have explored the characteristics that the smiles should have to be appropriate in an embarrassed, polite, or amused situation. However, we have not explored all possible meanings that the resulting smiles may signal. Depending on the context and on the message, the smiles may indeed be interpreted differently and consequently be appropriate in other contexts. Moreover, as shown in the decision tree, a same smile may produce several meaning depending on the perceiver. Finally, the error rate of each leaf in the decision tree gives the probability that the given smile reflects different meanings. However, even if the smiles are also appropriate in other contexts, it does not diminish their appropriateness in the contexts that we have considered in this paper. Consequently in situations of politeness, amusement, or embarrassment, the virtual agent can use theses smiles to successfully signal the appropriate state.

In the future we would like to focus on other smile types. Paul Ekman (1986) describes visual cues of 18 different smiles such as compliant, contemptuous, dampened, miserable, or flirtatious smiles. We plan to explore if different smiles within one category such as polite smiles may also be appropriate in other contexts to display different states. We would also like to study the influence of other morphological characteristics such as gaze, eyebrows, and head movement on the meaning of the smiles. Finally in this work we use only a few discrete values for both dynamic characteristics. In future we will study whether different sequences and timing of single action units may influence the meaning of a generated smile.

7 Acknowledgments

This research has been partially supported by the European Community Seventh Framework Program (FP7/2007-2013), under grant agreement no. 231287 (SSPNet).

References

- Ambadar, Z., Cohn, J., Reed, L.: All smiles are not created equal: Morphology and timing of smiles perceived as amused, polite, and embarrassed/nervous. *Journal of Nonverbal Behavior* 17-34 (2009) 238–252
- Beale, R., Creed, C.: Affective interaction: How emotional agents affect users. *Int. J. Hum.-Comput. Stud.* 67, 9 (2009), 755-776
- Breiman, L., Friedman, J., Olsen, R., Stone, C.: *Classification and Regression Trees*. Chapman and Hall (1984)
- Duchenne, G.: *The Mechanism of Human Facial Expression*. Cambridge University Press (1990 (1862))
- Ekman, P.: Darwin, deception, and facial expression. *Ann. N.Y. Acad. Sci.* 1000 (2003) 205–221
- Ekman, P., Friesen, W., Hager, J.: *The facial action coding system*. Weidenfeld and Nicolson (2002)
- Ekman, P.: *Telling lies: clues to deceit in the marketplace, politics, and marriage*. Berkley (1986)
- Ekman, P., Friesen, W.: Felt, false, and miserable smiles. *Journal of Nonverbal Behavior* 6 (1982) 238–252
- Ekman, P., Friesen, W.: *Unmasking the Face. A guide to recognizing emotions from facial clues*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey (1975)
- Fernandez-Dols, J., Ruiz-Belda, J.: Are smiles a sign of happiness? gold medal winners at the Olympic games. *Journal of Personality and Social Psychology* 69 (1995) 1113–1119
- Frank, M., Ekman, P., Friesen, W.: Behavioral markers and recognizability of the smile of enjoyment. *Journal of Personality and Social Psychology* 64 (1993) 83–93
- Grammer, K., Oberzaucher, E. (2006). The Reconstruction of Facial Expressions in Embodied Systems: New Approaches to an Old Problem, *ZIF Mitteilungen*, 2, 14-31.
- Harrigan, J.A., O'Connell, D.M.: How do you look when feeling anxious? Facial displays of anxiety. *Personality and Individual Differences* 21 (1996) 205–212
- Hess, U., Kleck, R.E.: Differentiating emotion elicited and deliberate emotional facial expressions. *European J. of Social Psychology* 20(5) (1990) 369–385
- Keltner, D.: Signs of appeasement: Evidence for the distinct displays of embarrassment, amusement, and shame. *Journal of Personality and Social Psychology* 68(3) (1995) 441–454
- Keltner, D., Buswell, B. N. (1996). Evidence for the distinctness of embarrassment, shame, and guilt: A study of recalled antecedents and facial expressions of emotion. *Cognition and Emotion*, 10, 155-171.
- Keltner, D., Buswell, B. N. (1997). Embarrassment: Its distinct form and appeasement functions. *Psychological Bulletin*, 122, 250-270.

- Krumhuber, E., Manstead, A., Cosker, D., Marshall, D., Rosin, P.: Effects of dynamic attributes of smiles in human and synthetic faces: A simulated job interview setting. *Journal of Nonverbal Behavior* 33 (2008) 1–15
- Krumhuber, E.G., Manstead, A.S.R.: Can Duchenne smiles be feigned? new evidence on felt and false smiles. *Emotion* 9(6) (2009) 807–820
- Mehrabian, A., Russell, J. A. (1974). *An approach to environmental psychology*. MIT Press, Cambridge.
- Niewiadomski, R., Hyniewska, S., Pelachaud, C., Evaluation of Multimodal Sequential Expressions of Emotions in ECA, in: *Proceedings of Third International Conference on Affective Computing and Intelligent Interaction (ACII 2009)*, Amsterdam, Holland, pp. 635-641, 200
- Niewiadomski, R., Pelachaud, C.: Model of facial expressions management for an embodied conversational agent. In: *2nd International Conference on Affective Computing and Intelligent Interaction (ACII)*, Lisbon, Portugal (2007) 12–23
- Ochs, M., Niewiadmoski, R., and Pelachaud , C. How a virtual agent should smile? Morphological and dynamic characteristics of virtual agent’s smiles, *Proceedings of the Intelligent Virtual Agent Conference (IVA)* (2010).
- Poggi, I., Pelachaud, C.: Emotional meaning and expression in performative faces. In: *Affective Interactions: Towards a New Generation of Computer Interfaces*. (2000)
- Rakotomalala, R.: Tanagra : un logiciel gratuit pour l’enseignement et la recherche. In: *Proceedings of EGC (Extraction etGestion des Connaissances)*. (2005) 697–702
- Rehm, M., Andre, E.: Catch me if you can exploring lying agents in social settings. In: *AAMAS*, Academic Press Inc (2005) 937–944
- Sabini, J., Siepmann, M., Stein, J., Meyerowitz, M.: Who is embarrassed by what? *Cognition and Emotion* 14 (2000) 213–240
- Tanguy, E.: *Emotions: the art of communication applied to virtual actors*. PhD thesis, Department of Computer Science, University of Bath, England (2006)
- Theonas, G., Hobbs, D., Rigas, D.: Employing virtual lecturers’ facial expressions in virtual educational environments. *International Journal of Virtual Reality* 7 (2008) 31–44
- Wang, N., Marsella, S., , Hawkins, T.: Individual differences in expressive response: a challenge for eca design. In: *International Joint Conference on Autonomous Agents and Multiagent Systems*. (2008) 1289–1292