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In Your Face, Robot! The Influence of a Character’s Embodiment on How Users Perceive Its Emotional Expressions

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Abstract

The ability of artificial characters to express emotions is essential for the natural interaction with humans. Their absence could be interpreted as coldness towards the user. Artificial characters can have different embodiments. Screen characters and robotic characters are currently among the most widely used. This study investigates the influence of the character’s embodiment on how users perceive the character’s emotional expressions. The results show that there is no significant difference in the perceived intensity and recognition accuracy between a robotic character and a screen character.

Another important aspect of the character is its ability to express different emotional intensity levels. Developers create different geometrical intensity levels of emotional expressions by equally dividing the spatial difference of each facial component between the neutral and maximum expression. However, the relationship between this geometrical intensity and the intensity perceived by the user might not be strictly linear. This study shows that also a quadratic trend is present in this relationship and that10% steps increase of geometrical intensity can often be distinguished whereas 20% steps can be distinguished almost all the time.

Introduction

Many synthetic characters are used for entertainment, communication, and work. They range from movie stars (Thomas & Johnson, 1981) and pets (Sony, 1999) to helper agents (Bell et al., 1997) (see Figure 1) and avatars for virtual cooperative environments (Isbister, Nakanishi, Ishida, & Nass, 2000). Characters can also have a physical body, e.g. robots. The interesting robots for this study help the elderly (Hirsch et al., 2000), support humans in the house (NEC, 2001), improve communication between distant partners (Gemperle, DiSalvo, Forlizzi, & Yonkers, 2003) and are research vehicles for the study on human-robot communication (Breazeal, 2003; Okada, 2001). A survey of relevant characters is available (Bartneck, 2002; Fong, Nourbakhsh, & Dautenhahn, 2003)

Figure 1: Synthetic characters: Aibo, eMuu, Microsoft Paperclip

The ability to communicate emotions is essential for a natural interaction between characters and humans because it is not possible not to communicate. The absence of a character's emotional expressions could already be interpreted as indifference towards the human. Therefore it is important that characters express their emotional state.

Robotic characters might be able to express their emotions better since their physical embodiment makes them more anthropomorphic than screen characters. However, assuming that screens are available, it is much easier to develop a screen character than a robotic character because a virtual world can be controlled easier. Robotic character s need to deal with uncertain sensory data and an unpredictable environment. A better ability to express emotions could possibly justify the extra effort of creating a robotic character.

Other factors have influence on the choice between a screen character or robotic character, such as if the character should be able to manipulate objects in the real world directly, or if it should be able to be in more than one place at a time. These factors might outweigh the question which of them is better able to communicate its emotional state, but if the main purpose of the character is to communicate with humans than this question might be essential.

Three parameters and their interaction are important for the comparison between the emotional expressions of a screen character and a robotic character: geometrical intensity, perceived intensity and recognition accuracy. We will now take a closer look at the three parameters.

Geometrical intensity

The synthetic face has certain components, such as eyebrows and a mouth, which can be manipulated. Usually, a maximum for each emotional expression is defined by reproducing already validated faces, such as the well-know Ekman faces (Ekman & Frieser, 1976). The spatial difference of each component between the neutral and the maximum expression is then divided into equal parts. To express 30% happiness, for example, the components are moved 30% of the distance between neutral and maximum.

Perceived intensity

Humans are able to judge the intensity of a human's or character's expression. Several studies have been carried out in which participants evaluated expressions (Etcoff & Magee, 1992; Hess, Blairy, & Kleck, 1997).

Recognition accuracy

Each emotional expression has a certain distinctness, which can be measured by the recognition accuracy of humans observing the expression. In this study, when we refer to recognition accuracy, we do not mean the differentiability between intensity levels within one emotion. We mean the differentiability between emotion categories measured as recognition rate. In such recognition tests the participants have to identify which emotion was expressed. Low intensity expressions are usually less distinct (Bartneck, 2001; Etcoff & Magee, 1992) but can play an important role in human communication (Suzuki & Bartneck, 2003).

Focus of this study

The main focus of this study is to determine if the embodiment of the characters has an influence on its ability to express emotions. This ability will be determined by the parameters mentioned above. In addition we will take a look at the relationships of these three parameters. Clearly, the geometrical intensity has a direct influence on the perceived intensity and the recognition accuracy of the expression. The closer the emotional expression is to its maximum the higher is the perceived intensity and the recognition accuracy of the expression. However, it cannot be assumed that this relationship is as simple as the function *perceived intensity = geometric intensity*. A 30% geometrical intense expression of happiness may not be perceived to be 30% intense or correctly recognized in 30% of the cases.

Research questions

Based on the background given above we would like to define the four research questions of this study:

1. Do robotic characters express emotions better than screen characters?
2. What is the relationship between the geometrical and perceived intensity?
3. What is the influence of the geometrical intensity on the recognition accuracy of the expression?
4. What is the relation between perceived intensity and the recognition accuracy of the expression?

Related work

Hess, Blairy & Kleck (1997) studied the relationship between the geometrical intensity of an emotional expression and the perceived intensity and the recognition of that expression using pictures of natural faces as stimuli. They changed the geometrical intensity by combining a neutral face with an intense expression of an emotion using graphic morphing software in 20% steps. This is problematic since it is impossible to control how the morphing software merges the pictures and therefore generates steps of 20% intensity.

Hess et al. found a significant main effect of physical intensity for both perceived intensity and recognition accuracy. With increasing geometrical intensity, perceived intensity increased in a linear way. For recognition accuracy a significant linear and quadratic trend was found. Furthermore, task difficulty was rated lower for higher intensities. Besides, happiness was the easiest to recognize and it was recognized the best: almost 100% correct identifications even for low physical intensities. This happy face advantage has been reported before (Ekman & Friesen, 1971). Hess et al. argue that their results support the theory of categorical perception only for happiness, not for the other emotions.

In our study, we hope to replicate their results regarding the perceived intensity with different stimuli, namely robotic characters and screen characters. Regarding the recognition accuracy, we want to find out if we can support a categorical or a dimensional perception of emotional expressions. In the present study, however, we do not use the critical morphing procedure to create different intensity levels. Instead, we use an robot animation tool as described in the Methodology section below.

Differences in identification of emotions between natural and synthetic faces were researched by Kätsyri, Klucharev, Frydrych & Sams (2003). They found that emotional expressions shown by a synthetic talking head that they developed (Frydrych, Kätsyri, Dobsik, & Sams, 2003) was recognized worse than emotional expressions displayed by natural human faces. This suggests that synthetic faces are not an adequate alternative for natural faces. On the other hand there is research that shows that emotional expressions by synthetic faces are recognized as well or even better than emotions on natural faces (Bartneck, 2001; Katsikitis, 1997).

Another aspect of emotional expressions is of interest to this study. The space of human emotions is frequently modeled either with dimensions, such as arousal and valence (Hendrix et al., 2000; Osgood, Suci, & Tannenbaum, 1957; Russel, 1979; Schlossberg, 1954) or in categories such as happiness and sadness (Ekman, Friesen, & Ellsworth, 1972; Izard, 1977; Plutchik, 1980). It has already been shown that a two dimensional space is insufficient to accurately model the perception of emotional facial expressions (Schiano, Ehrlich, Rahardja, & Sheridan, 2000). Etcoff & Magee (1992) showed that emotional facial expressions are perceived categorically.

They used line drawings of emotional faces to study the relationship between physical intensity of an emotional facial expression and the recognition. They had their subject identify an emotion on 11 evenly spaced facial expression continua. The continua were based on merging either a neutral face with an emotional expressive face or on merging two faces with different emotional expressions. It was found that emotions were perceived categorically, except for surprise. That means that small physical differences in emotional facial expressions are easier to distinguish when at boundaries between emotions and harder when within one emotion category. In our study we only use neutral – emotion continua for 5 emotions. We expect to find a boundary for each emotion where it is possible to recognize an expression as a particular emotion.

Design of the Robot

Work at Philips Research currently focuses on building user-interface robot's to facilitate natural dialogues for home automation. For this purpose, a dedicated user-interface robot has been developed that provides an interface to devices in the "HomeLab", an Ambient

Intelligence Home environment (Aarts, Harwig, & Schuurmans, 2001). Figure 2 shows the robot, which is called iCat and has a height of 38 cm. The robot performs various functions using the home network, such as information gathering on the Internet and device control (lights, VCR, radio, etc.).

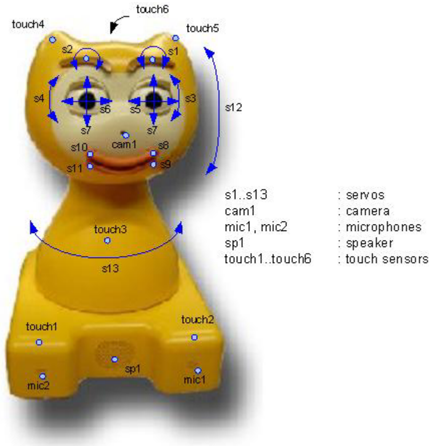

Figure 2: The degrees of freedom of the iCat Robot

Interacting with the iCat should be enjoyable and effective. Therefore, we provided the user interface robot with facial expression capabilities that make the communication between the robot and a user more natural. Mobility capabilities were left out of our design in order to solely concentrate on face to face interaction.

To determine the components of the face that should be manipulated to create a particular facial expression, we analyzed facial expressions of cartoon characters. We concluded that by controlling the eyebrows, eyelids, and mouth components we are at least able to express the six basic facial expressions (happiness, anger, sadness, surprise, fear, disgust). In addition to these facial components, we also decided to control the eyes (look up/down and left/right), the head (up/down) and body (left/right), because these parts also are involved in head to head communication. All parts of the robot are controlled by 13 standard R/C servos. These servos rotate with a 1 degree precision, which gives us the possibility to accurately vary the position of the facial components and thus to create different intensities of the facial expression. Figure 3 shows some of the facial expressions that can be realized by this configuration.

A camera is installed in the nose of the iCat for face recognition and head tracking. iCat's foot contains two microphones to record sound it hears and to determine the direction of the sound source. Also, a speaker is installed to play sounds (WAV and MIDI files) and to generate speech. Finally, several touch sensors are installed to sense whether the user touches the robot.

The control software of the robot is implemented using the Dynamic Module Library (Breemen et al., 2003). A software module was implemented that calculated the positions of the servos for a given emotion and intensity. This is done by linearly interpolating the servo positions at the maximum intensity with the servo positions at the neutral position of an emotion. A second software module realized an interface between the robot and an Internet webpage that ran the experiments.

Methodology

We reproduced the method used by Hess, et al. (1997) to allow a comparison of the results, with two exceptions. First, we used a 11-point scale instead of a continuous slider, which should not have any effect on the validity of the comparison. Second, we used 10% steps of geometrical intensity instead of Hess' et al. 20% steps. This offers more fine-grained analyses, while still enabling us to compare the results by only considering every second intensity step.

Unlike Hess et al. who did their study with morphed natural faces, we used a robotic characters and movies of the robotic character. These robotic faces differed in the percentage of the angles of the mouth, the eyebrows and the eyes from the neutral position (0 percent) to the extreme position (100 percent).

Subjects

56 people participated in the experiment. They consisted of 18 female and 38 male ranging from 16 to 57 years of age (M = 23.98, SD = 8,57). They were split randomly across the conditions. The participants received a reward at the end of the experiment.

Design

A mixed 5 (emotion) x 10 (intensity) x 2 (embodiment) experiment was conducted. Emotion and intensity were within subject factors and embodiment was as a between subject factor. The dependent variables were perceived intensity, recognition accuracy and task difficulty.

Perceived intensity. Participants were asked to rate the intensity of the emotions anger, contempt, disgust, fear, happiness, sadness, and surprise on 11-point scales for each presented schematic face. Each scale was labeled with an emotion and anchored with „not intense at all“ and „very intense“.

Recognition Accuracy. The intended emotion was considered correctly identified if it received a highest rating on the correct scale. The recognition rate defines the distinctness of an emotion.

Task difficulty. The task difficulty had to be rated on a 5-point scale anchored by the labels "very easy" and "very difficult".

Material

The iCat robot, developed by Philips Research (Breemen, 2004) was used to create the conditions of the experiment (see Figure 3). In the robot condition the iCat itself was placed on a table in front of the participants and expressed the five emotions. In the screen condition movies of the iCat expressing the five emotions were played on a computer screen in front of the participants.

The intensity factor consisted of ten evenly spaced levels of each emotion. Manipulating the angle of the eyebrow, the mouth and the eyes varied the intensity of an emotion. The intensity of each expression started with 10% of the maximum angle, and was increased by 10% steps, ending with the highest emotion at 100% geometric intensity.

The emotion factor consisted of five basic emotional expressions (see Figure 3) namely anger, fear, happiness, sadness, and surprise. The disgust expression was excluded because it received very low recognition ratings in a pilot test.

Figure 3: The five most intense faces and the neutral face.

Procedure

The experiment took place in a lab in the TU Eindhoven and took about 30 minutes. After the participants read instructions on a computer screen they were shown the most intense faces and the neutral face before they entered a practice session. In the practice session they had to evaluate three different faces. In the robot condition, participants were asked to look at the robot, which was standing on a desk in front of them. The robot displayed an emotion for 5 seconds and then returned to the neutral face. In the screen condition the participants were shown a face for five seconds on a computer screen. After seeing the face the participants had to fill in a questionnaire on a computer screen (see Figure 4). They had to fill in seven intensity rating scales and one difficulty scale. They could not continue before all scales were filled in. When an expression was shown and subjects thought certain emotions to be irrelevant for that expression, they were supposed to mark those irrelevant emotions with "not intense at all".

After the practice session the participants could ask questions about the process of the experiment. Afterwards, the experiment started. The structure of the experiment is identical to the practice session. However, now the participants had to evaluate all 50 faces that were shown in random order. After the experiment the participants were debriefed.

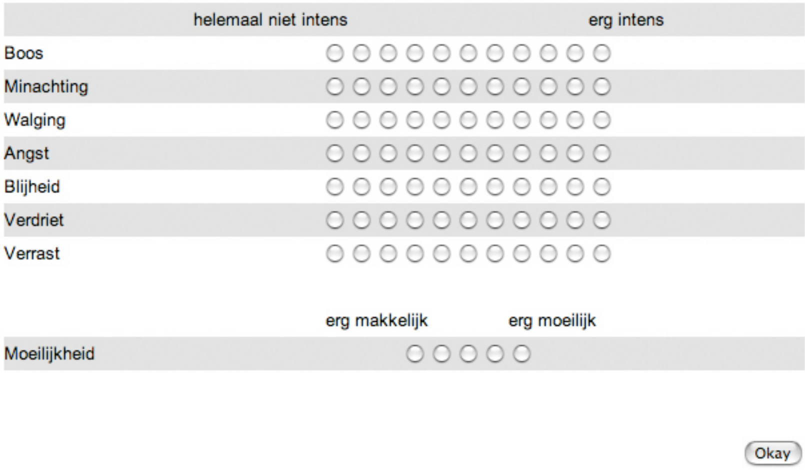

Figure 4: The questionnaire

Results

Relationship between geometrical intensity and perceived intensity

A 5 (emotion) x 10 (geometric intensity) x 2 (embodiment) ANOVA with emotion and geometric intensity as within subject factors and embodiment as between subjects factor was conducted. Emotion and geometric intensity had an significant effect on perceived intensity (emotion: $F(4, 216) = 57.485$, $p < .001$; geometrical intensity: $F(9, 486) = 146.019$, $p < .001$). Faces with higher geometric intensity received higher intensity ratings. Robot faces tended to receive higher intensity rating than the screen faces but this difference shortly missed significance ($F(1, 54) = 3.863$, $p = 0.055$).

A linear ($F(1, 54) = 551.633$, $p < .001$) and quadratic ($F(1, 54) = 33.375$, $p < .001$) trend was present in the relationship between geometrical and perceived intensity. Figure 5 visualizes the relationship.

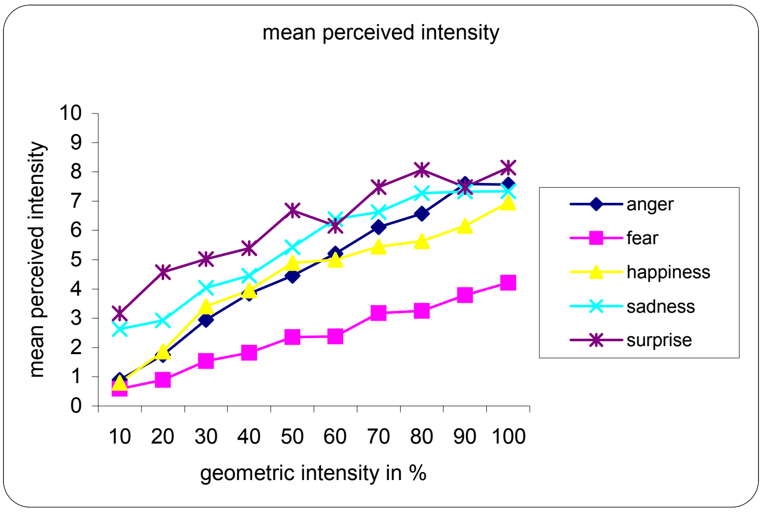

Figure 5: Mean perceived intensity

To evaluate which consecutive intensity levels differed significantly, we calculated repeated contrasts for each emotion across the embodiment condition. F and p values for the differences between consecutive levels can be seen in

Table 1. Printed in bold are significant differences between consecutive intensity levels. That means that intensity differences in the emotional facial expressions are indeed perceived, mainly in the lower intensity expressions.

Levels	Anger		Fear		Happiness		Sadness		Surprise	
%	F(1,55)	p	F(1,55)	p	F(1,55)	p	F(1,55)	p	F(1,55)	p
10-20	5.702	**.020**	2.186	.145	9.167	**.004**	.721	.400	9.557	**.003**
20-30	7.590	**.008**	7.197	**.010**	18.534	**.000**	4.619	**.036**	.797	.376
30-40	5.345	**.025**	.869	.355	2.541	.117	1.193	.280	.647	.425
40-50	2.632	.110	1.930	.170	6.066	**.017**	5.659	**.021**	12.139	**.001**
50-60	5.640	**.021**	.002	.968	.088	.768	7.021	**.010**	1.559	.217
60-70	3.217	.078	3.037	.087	1.490	.227	.328	.569	8.480	**.005**
70-80	.755	.389	.034	.855	.164	.687	2.018	.161	2.586	.114
80-90	4.171	**.046**	.919	.342	1.761	.190	.028	.867	1.683	.200
90-100	.001	.969	1.060	.308	5.669	**.021**	.004	.950	2.478	.121

Table 1: Differences in perceived intensity between consecutive geometric intensity levels.

Relationship between geometrical intensity and recognition

A 5 (emotion) x 10 (geometric intensity) x 2 (embodiment) ANOVA with emotion and geometric intensity as within subject factors and embodiment as between subjects factor was conducted. Recognition accuracy differed significantly between emotions ($F(4, 216) = 88.780$, $p < .001$) and between geometric intensity levels ($F(9, 486) = 36.514$, $p < .001$). Faces with higher geometric intensity received higher intensity ratings. There was no difference in recognition accuracy between robot and screen condition ($F(1, 54) = .338$, $p = .563$).

Figure **6** shows the relationship between geometrical intensity and recognition accuracy.

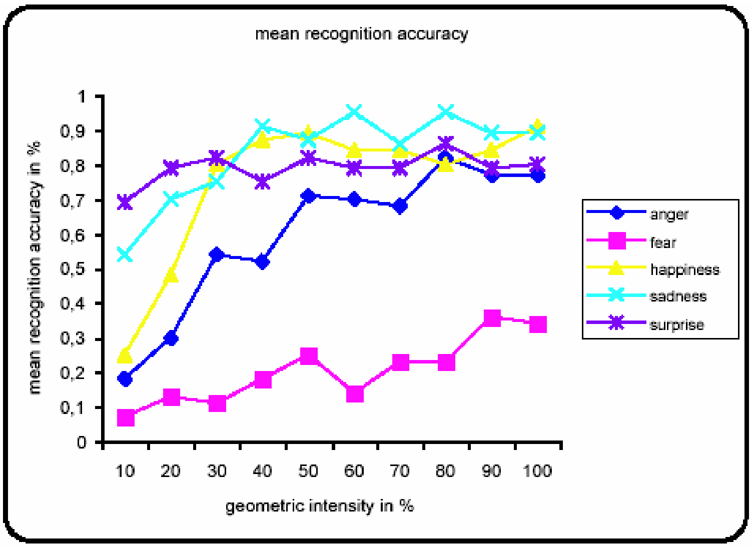

Figure 6: recognition accuracy per emotion

To find out for what intensities the recognition rate was significantly lower compared to the maximum intensity of 100%, we tested simple contrasts with the highest intensity level for each emotion across embodiment conditions (see

Table **2**). Geometric intensity did not have a significant influence on recognition accuracy for surprise ($F(9, 495) = .877$, $p = .546$) Significant differences are printed in bold. It can be seen that emotional facial expressions were recognized less well when they were not very intense, but were recognized just as well as the full-.blown emotion when at least 50% intensity was given.

Intensity	Anger		Fear		Happiness		Sadness		Surprise	
%	F(1, 55)	p	F(1, 55)	p	F(1, 55)	p	F(1, 55)	p	F(1, 55)	p
10	78.913	**.000**	17.022	**.000**	107.105	**.000**	18.733	**.000**	2.053	.158
20	37.032	**.000**	7.279	**.009**	36.000	**.000**	7.941	**.007**	.066	.799
30	9.230	**.004**	10.385	**.002**	3.779	.057	4.185	**.046**	.076	.784
40	9.390	**.003**	5.115	**.028**	.663	.419	.152	.698	.596	.444
50	.596	.444	1.687	.199	.329	.568	.101	.752	.066	.799
60	1.000	.322	8.008	**.006**	2.037	.159	1.877	.176	.076	.784
70	1.195	.279	2.037	.159	2.750	.103	.380	.540	.076	.784
80	.688	.410	2.037	.159	6.600	**.013**	1.328	.254	.815	.370
90	.000	1.000	.076	.784	2.037	.159	.000	.987	.089	.766

Table 2: Differences in recognition rate between the highest geometric intensity of 100% and lower intensities.

Relationship between geometrical intensity and difficulty

A 5 (emotion) x 10 (geometric intensity) x 2 (embodiment) ANOVA with emotion and geometric intensity as within subject factors and embodiment as between subjects factor was conducted.

Difficulty differed significantly between emotions (F(4, 216) =15.505, p < .001) and between geometric intensity levels (F(9, 486) = 28.747, p < .001). Faces with higher geometric intensity were easier to rate. There was no difference in difficulty between robot and video condition (F(1, 54) = .629, p = .431 Figure 7 illustrates the relationship between geometrical intensity and difficulty.

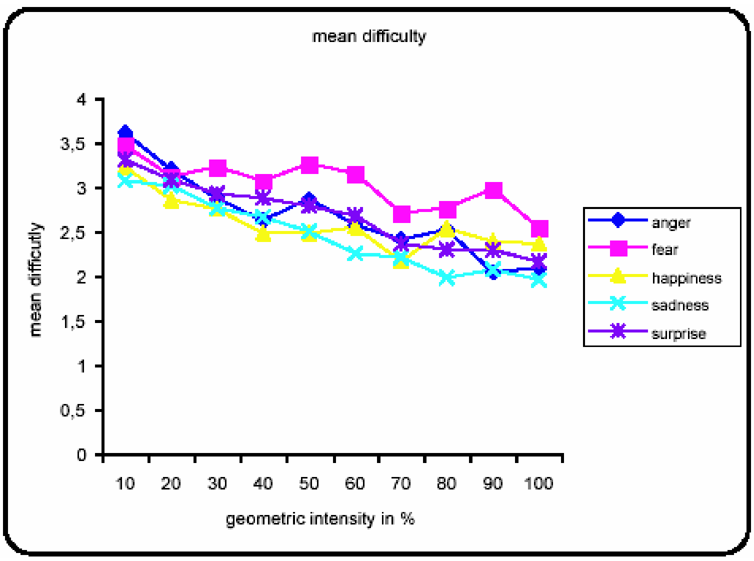

Figure 7: Difficulty per emotion

To see if it was any more difficult to judge a low intensity emotion we tested simple contrast with the highest intensity for each emotion across embodiment conditions. See Table **3** for the results. Printed in bold you find the significant results. You can see that low intensity expressions are harder to rate than the full-blown emotion.

Intensity	Anger		Fear		Happiness		Sadness		Surprise	
%	F(1, 55)	p	F(1, 55)	p	F(1, 55)	p	F(1, 55)	p	F(1, 55)	p
10	62.255	**.000**	24.449	**.000**	14.026	**.000**	31.445	**.000**	29.585	**.000**
20	27.486	**.000**	7.776	**.007**	5.500	**.023**	22.305	**.000**	26.110	**.000**
30	24.557	**.000**	13.852	**.000**	4.269	**.044**	21.601	**.000**	26.713	**.000**
40	13.827	**.000**	10.789	**.002**	.616	.436	14.808	**.000**	15.193	**.000**
50	25.208	**.000**	15.149	**.000**	.632	.430	9.568	**.003**	18.474	**.000**
60	11.551	**.001**	12.648	**.001**	1.072	.305	3.679	.060	13.326	**.001**
70	5.115	**.028**	1.089	.301	1.435	.236	1.986	.164	2.249	.139
80	8.354	**.005**	1.805	.185	1.256	.267	.021	.886	.636	.429
90	.197	.659	5.589	**.022**	.036	.851	.692	.409	.616	.436

Table 3: Differences in difficulty between the highest geometric intensity of 100% and lower intensities.

Discussion

Influence of the embodiment

The embodiment of the character had no significant influence on how people perceive its emotional expression.

Relationship between geometrical intensity and perceived intensity

The perceived intensity increased with higher geometric intensity. Given geometrical intensity level steps of 10% the consecutive perceived intensity levels differed mainly at low geometrical intensity levels but not at the higher levels. It seems that the 10% geometrical intensity level steps are too small to be discriminated. For a practical application it appears useful to use 20% steps to ensure that the user can distinguish the different levels.

Figure 5 shows the relationship between geometrical and perceived intensity. The graph shows that this relationship cannot be modeled by a simple linear function, such as perceived intensity = geometric intensity but that a curve-linear trend is visible consisting of a linear trend and a quadratic trend.

Relationship between geometrical intensity and recognition

The recognition accuracies for each emotion increased with the geometric intensity up to a certain point where the recognition accuracy did not significantly differ anymore from the recognition accuracy at the maximum geometrical intensity of each emotion. This point was reached at 40% geometrical intensity for anger and fear at 30% for sadness and at 20% geometrical intensity for happiness. This happy-face bonus was previously observed (Ekman & Friesen, 1971). Our results show that it is possibly to communicate emotions also at low intensity levels and thereby enable characters and robots to act more subtle.

Relationship between geometrical intensity and difficulty

Although participants were able to recognize the emotions even at low intensities, it was still more difficult for them compared to high intensity expressions. This result is in line with our expectations. Fear remains a problematic emotional expression because it was difficult to identify at low and high intensity. In addition it was the most difficult emotion to identify.

Conclusions

We conducted a study of synthetic facial expression of robotic characters and screen characters. We investigated the influence of the embodiment and the relationships between geometrical intensity, perceived intensity, recognition accuracy and difficulty.

Robotic characters are not able to express emotions better than screen characters. Their more anthropomorphic shape does not help to express emotions and hence developers of robots should focus on other advantages of robots to justify their development. This could be the possibility of tactile interaction and direct manipulation of the environment. Screen characters simply cannot bring you a cup of tea.

Fear and happiness remain two special emotional categories for facial expressions. The happy-face advantage shows how sensitive humans are in perceiving positive expressions. Since the repertoire of positive expressions is limited to smiling it is good to know that it is also correctly recognized at low intensities. Fear is a problematic expression since it is difficult to recognize and to judge its intensity.

The results of our study indicate that emotional expressions might be perceived categorically. The strong increase of recognition accuracy at about 30% geometrical intensity could be interpreted as categorical perception as described by Etcoff and Magee (1992). However, we have only explored facial expression between neutral face and most intense face for each emotion and not between two different emotions. Therefore our results can only be an indication.

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