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Analysis of emotion recognition through 2D micro-animations of an illustrated character's face

ABSTRACT

Emotions make up a large part of everyday communication. Humans learn to recognize emotions by observing others and by referencing their feelings with the emotions of other people. Also, in cartoons, commercials, posts, etc., it's important that the design of the characters keeps the recognition of emotions high. Expressed emotions provide a better connection between the character and the viewer, making the message more understandable and tangible. This study analyses the recognition of animated facial expressions depicting different emotions on the face of an illustrated character. The accuracy of recognition of six basic emotional expressions (joy, sadness, anger, surprise, fear, and disgust) was compared. Using micro-animation techniques, each emotion was presented in three levels of intensity (a subtle version, a normal version, and an exaggerated version). Emotion recognition was analysed with a method of metric analysis of viewing and surveying that measured recognition time and accuracy in addition to the correctness of the characters' emotion recognition. Statistically relevant differences between the results of animated emotion recognition as a function of recognition time and type of recognition task were examined. The results show how recognition changed as a function of the emotion shown and intensity, and provide a deeper understanding of micro-animations and facial expressions on the animated character's face. Statistically relevant differences were found especially in the recognition of the emotions disgust and anger compared to the recognition of the emotions joy, surprise, fear. Based on the results, guidelines are given to help animators answer the question of which emotions need to be particularly exaggerated to be correctly recognised and which emotions can be animated more subtly without affecting emotional perception.

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Introduction

Emotions represent an important communication moment with which we communicate the quality of the message, in the sense of whether it is happy, restrained, angry, surprised... The message is communicated verbally, with gestures, body movements, etc. Just like in real life, the recognition of emotions in the faces of animated characters is important to convey the character's feelings and thoughts, the atmosphere and story, as animated characters are often used in communication media (advertising, entertainment, online production, social networks, etc.). Perception of emotions and their recognition allows the viewer to feel deeper the happening in the animation, to understand it and to empathize with the animated characters.

As researcher P. Ekman writes in his book Emotions Revealed (2003), positive, pleasant-oriented emotions can help us live a better and happier life, while less pleasant and more negative-oriented emotions can seriously

harm us. Can we completely suppress and manipulate emotions to disguise what we really feel? This is what Paul Ekman wondered in his research on emotions and micro-expressions (Ekman, 2003; Ekman, 1993). In his long-term research, he was looking for a special indicator that would reveal how persons really feel, even if they want to hide it. In his research, he focused on observing the face and found that there are indicators for every emotion, which he called micro and macro expressions. These are small, unconscious micro or macro movements of the facial muscles that indicate the onset of an emotion or the presence of the emotion, even if the person is hiding it. Since the movements are unconscious, it is very difficult for people to hide them. Thus, a method for detecting emotions was developed, which comes from the theory of micro-expressions and is used in determining the truth, in interrogations, negotiations, and similar situations in which there is a need to discover whether the interlocutor is trying to hide something or whether he or she is being honest (Ekman, 2003; Ekman, 1993).

In his research, Ekman divides emotions into five basic groups: sadness and anxiety, anger, surprise and fear, disgust and contempt, and many types of joy. He divided the emotions into the aforementioned groups because he found that the micro-movements for the emotions within these groups were very similar to each other. It also turned out that all people, regardless of their cultural or geographic background, assigned the same emotional label to each of the micro-expression images. Thus, it can be concluded that micro-expressions related to the representation of individual emotions are the universal language of all people in the world (Ekman, 2003; Ekman, 2022; Ekman, 2016). In his research (Ekman, 2022), Ekman also claims that we can only recognize emotions by observing the right parts of facial expressions. Thus, he divides the facial movements that show emotion into micro-expressions, which represent large changes in facial expression and therefore can be recognized by most people, and micro-expressions, which represent smaller movements in facial expression that are sometimes almost imperceptible and therefore can be overlooked by many people (Strgar, 2019; Iskra, 2020).

Animation of emotions

An emotionally neutral character is one without emotions or feelings and serves as a base before transitioning into a single emotion. Such a character is characterized by being relaxed and showing no emotion (Kehr, 2023; Hooks, 2015; Thomas & Johnston, 1995).

To build up the animation of emotions we can use the representation of different intensities of emotions. There are three basic intensity levels: very low representation, medium representation, and very emotional representation. Between the two extremes, there is a whole spectrum of inter-intensities that can serve as transition or also as a main emotional representation. Different intensities of emotion are always used in character's animation depending on the circumstances, the story, the character's personality, the animation style, etc. (Boucher & Ekman, 1975; Hooks, 2015; King, 2001).

Secondary animation, one of the Disney's animation principles, includes movements that support the main movement of the character in the animation, adding more dimensions to the animation of the character. This principle is important in creating the animation of an emotional state and can include movements and actions as breathing, blinking, movements of the head, hands, or other body parts (Webster, 2005; Eisner, 1958; Veler, 2018).

Which emotions are to be emphasized in animation and when during the plot depends mainly on the story, the character's personality, and the circumstances in the story. Generally speaking, however, anger, sadness, and joy are usually strongly emphasized in animation because these emotions are very familiar to all viewers, regardless of age, gender and also cultural differences (Kehr, 2023; Lasseter, 2001; Pranjić, 2015).

Breakdown of individual emotions by micro-expressions and animation features

According to Paul Ekman, anger is expressed on the face in such a way that the eyebrows are drawn together, the eyes look far forward, the nostrils are flared, and the lips are pressed together. In a more hidden, subtle version of the emotion display, we can recognize characteristic unconscious micro-expressions such as tense eyebrows, fixed eyes, and slightly more compressed lips (Ekman, 1993; Prajnić, 2015; Babich, 2016). In the animation, joy is shown by squeezing the eyes from below, often giving them a C-shape at the bottom, and by drawing wrinkles around them starting from the corners of the eyes. The cheeks lift and bulge, and the mouth contorts into a smile where the teeth can be seen. In covert, unconscious micro-expressions, joy is shown only by a slight lifting of the corners of the lips and eyes (Ekman, 1993; Prajnić, 2015; Babich, 2016; Williams, 2001; Adegbola, 2008). In animations, surprise is often greatly exaggerated because it is a very fleeting emotion and therefore needs to be emphasized in order to truly convey it to the viewer. For example, in many animations the eyebrows are particularly high, sometimes even completely outside the face, and the mouth is very wide open, in some cases the jaw even reaches the floor (Ekman, 1993; Prajnić, 2015; Babich, 2016).

The most characteristic sign of disgust is the wrinkling of the nose, which does not occur with any other emotion. Disgust is also shown by lowered eyebrows, which are fairly straight and slightly lowered only at the

inner part, the upper lip is raised into an inverted U, and the lower lip is raised and slightly tilted outward. However, disgust appears as an unconscious micro-expressions with a small squinting of the eyes and an almost imperceptible wrinkling of the nose (Ekman, 1993; Babich, 2016, Prajnić, 2015; Roberts, 2011). Fear appears on the face with raised eyebrows pushed together toward the center of the face, raised upper eyelids, and tense lower eyelids. The mouth is slightly open, and the corners of the lips are pressed down. However, in a subtle way, it appears as a micro-expression with slightly dilated eyes and slightly open mouth (Ekman, 1993, Prajnić, 2015; Babich, 2016; Roberts, 2011).

The most characteristic features of the face for sadness are the eyebrows, which are drawn upward at the inner ends away from the eyes and move slightly together toward the center of the face. The upper eyelids droop and the eyes look more downward, and the corners of the mouth are also pulled downward. As an unconscious micro-expression, however, the sadness is barely perceptible, as it is expressed only in slightly drooping corners of the mouth and a slightly lowered gaze (Ekman, 1993; Babich, 2016). In animation, sadness is often accompanied by crying and tears (Roberts, 2011; Prajnić, 2015).

Recognition of emotions in static images (photos) or videos is a very well researched field (Reynolds & Przdek, 1992; Rus, 2003; Or & Wilson, 2015; Guo & Shaw, 2015; Leyk et al., 2008; Kramer, Youn & Burtona, 2018; Tarnowski et al., 2017; Strgar, 2019; Iskra, 2020), while this cannot be said for the field of representation of emotions in animations. Based on the study of facial anatomy and expressions, as well as many years of experience, animators, designers, and artists create emotions in the faces of characters, but there are few studies that analyze and metrically evaluate the effects of creating emotions in characters.

Zhang et al. (2021) compared and determined the importance of individual facial features on the perception of emotion by superimposing parts of respondents' faces. They compared the perception of imaged and photographed faces and found, among other things, that the mouth was most important for the perception of joy and the eyebrows were most important for the detection of sadness, which is also supported by some other sources (Strgar, 2019; Iskra, 2020). Brosnan et al. (2015), in a study entitled Emotion recognition in animated compared to human stimuli in adolescents with autism spectrum disorder, also conducted interesting research in the area of emotion perception, in which they examined emotion recognition in illustrated and photographed faces in children with autism. They found that children with autism recognized emotions much better than the control group when recognizing animated images, while they had much more difficulty recognizing them with photographs. Micro-expression recognition in animated figures was also studied by Hou (2021). In his research it was found that the amount of exaggeration of individual micro-expressions and the illustration style used in the animation had a very large impact on the final perception.

As we can see, some researches have been conducted in the field of emotion perception in illustrated or animated figures, and each had chosen its own perspective on the subject. All the researches focused on the same emotions (joy, sadness, anger, disgust, surprise, and fear). However, due to the specificity of the research topic, some studies focused on a smaller number of emotions from the defined set. In some studies, the individual emotions were also divided into different intensities and analysed separately.

The aim of the research was to systematically study the facial parts of the author-illustrated character for animation, to study the micro-movements that occur when a particular emotion is expressed, and how much the animator needs to exaggerate the representation of a particular emotion in animation in order for the viewer to perceive the emotion. The goal was also to list guidelines that can help animators answer the question of how parts of the face have to be designed in animation for the correct recognition of the emotion, and for which emotions it is sufficient to design the facial movements at a more subtle level so that the result of recognizing the emotion is still adequate. We also analysed the temporal recognition of different emotions as a function of the sequential presentation of emotion animations of a particular style to respondents, i.e., how quickly the viewer recognizes a particular emotion in a particular expression style of animated presentation when it is shown the first, second, and then third time.

We hypothesized the following:

H1: Better perception of emotions by viewers of a 2D animated face will occur with more intense emotion representations.

H2: The most intense representation of emotion in an animated character is necessary for the perception of sadness.

H3: The least intensity of emotion representation is required for perception when representing anger and joy.

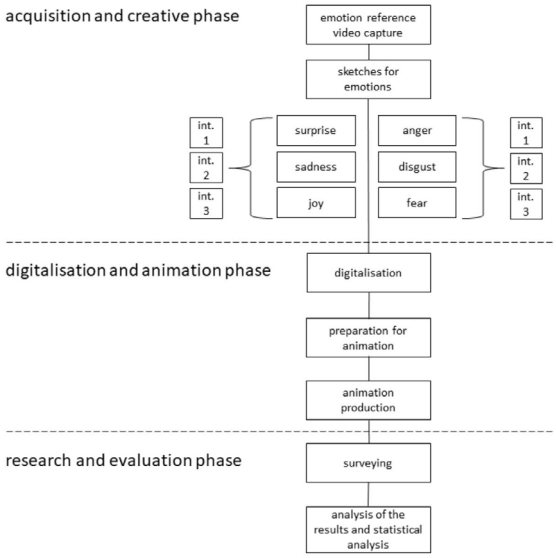
H4: Faster perceptions are recorded for the most intense representation of emotions.

H5: Respondents perceive a representation of joy most quickly.

H6: Respondents perceive a representation of sadness most slowly in time.

Experimental Part

The experimental part followed the flowchart shown in Figure 1, with acquisition and creative phase (illustration and emotion expression), digitalisation and animation phase and research and evaluation phase.

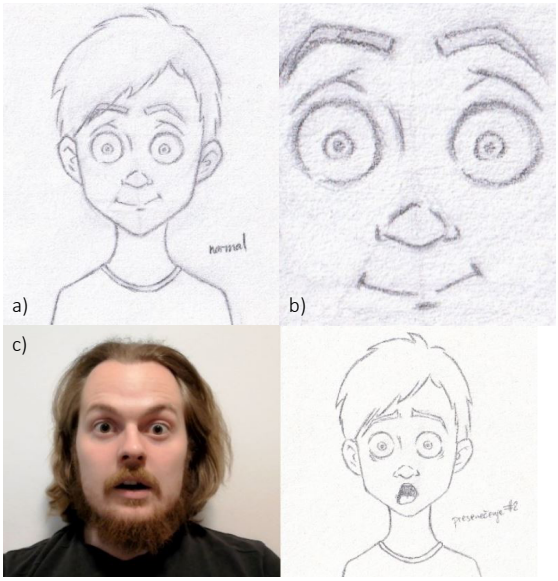


» **Figure 1:** *Organogram showing the flow of research to results (int. means intensity of indicated emotion)*

In this paper, the terms recognition and perception are used to identify the emotions on a character's face. In the literature, the general term recognition is used, while the term perception is used for the recognition of micro-animations. At the beginning of the study, we recorded the selected emotions (joy, anger, fear, disgust, surprise, and sadness) expressed with the human face of three different individuals (a kid – age 12, a young man – age 26 and a man of middle age – age 46).

Participants volunteered to have their faces and expressions photographed. For each person, we recorded three recordings of all three intensity levels of the emotion, i.e., the representation of a mild, subtle version, a normal representation, and an exaggerated version of the representation of a selected emotion (Figure 2).

This was the starting point and reference for preparing the representation of emotion on our illustrated character. We paid special attention to the movements of facial parts such as eyebrows, eyes, mouth, nose, jaw, and the movements of facial folds. When designing the character, it was very important that the basic expression on character's face is as neutral as possible, as shown in Figure 3. In order to show a neutral face, we chose a character's face that eliminates the differences between the sexes as much as possible.

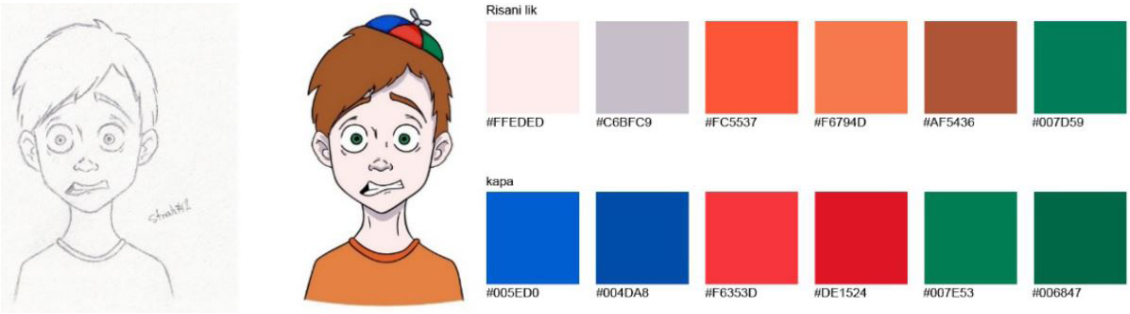


» **Figure 3:** *The original sketch of our character (a), the sketch of the moving parts of the face (b) and the outline of the surprise according to the reference (c)*

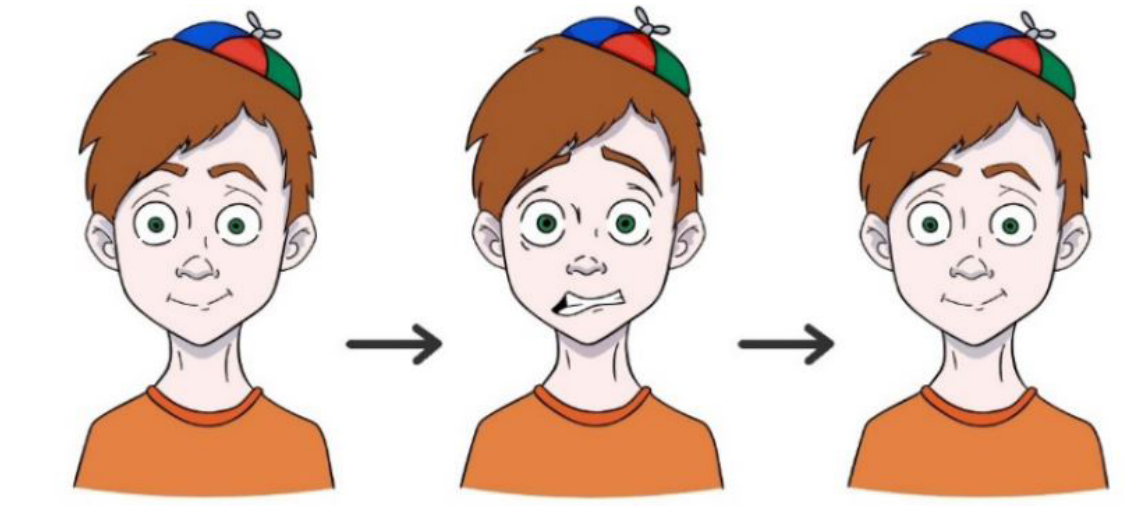
We made eighteen sketches of emotions for three intensities and the representation of each of the six selected emotions (Figure 4 shows joy). We took into account the theory of micro-expressions, which are visible even when the display of emotion is minimal or hidden. We vectorized the drawings and determined the colour palette (Figure 5). The digital illustration of the character and colour palette are shown in Figure 5. The changes from a neutral to an emotional face for the purpose of analysis were animated in such a way that they could be played back in an uninterrupted repeating loop (Figure 6).

» **Figure 2:** *A picture of three intensities of joy on a young man*

» **Figure 4:** *Illustrations of the three joy intensities*



» **Figure 5:** *Digital illustration of the character and colour palette*



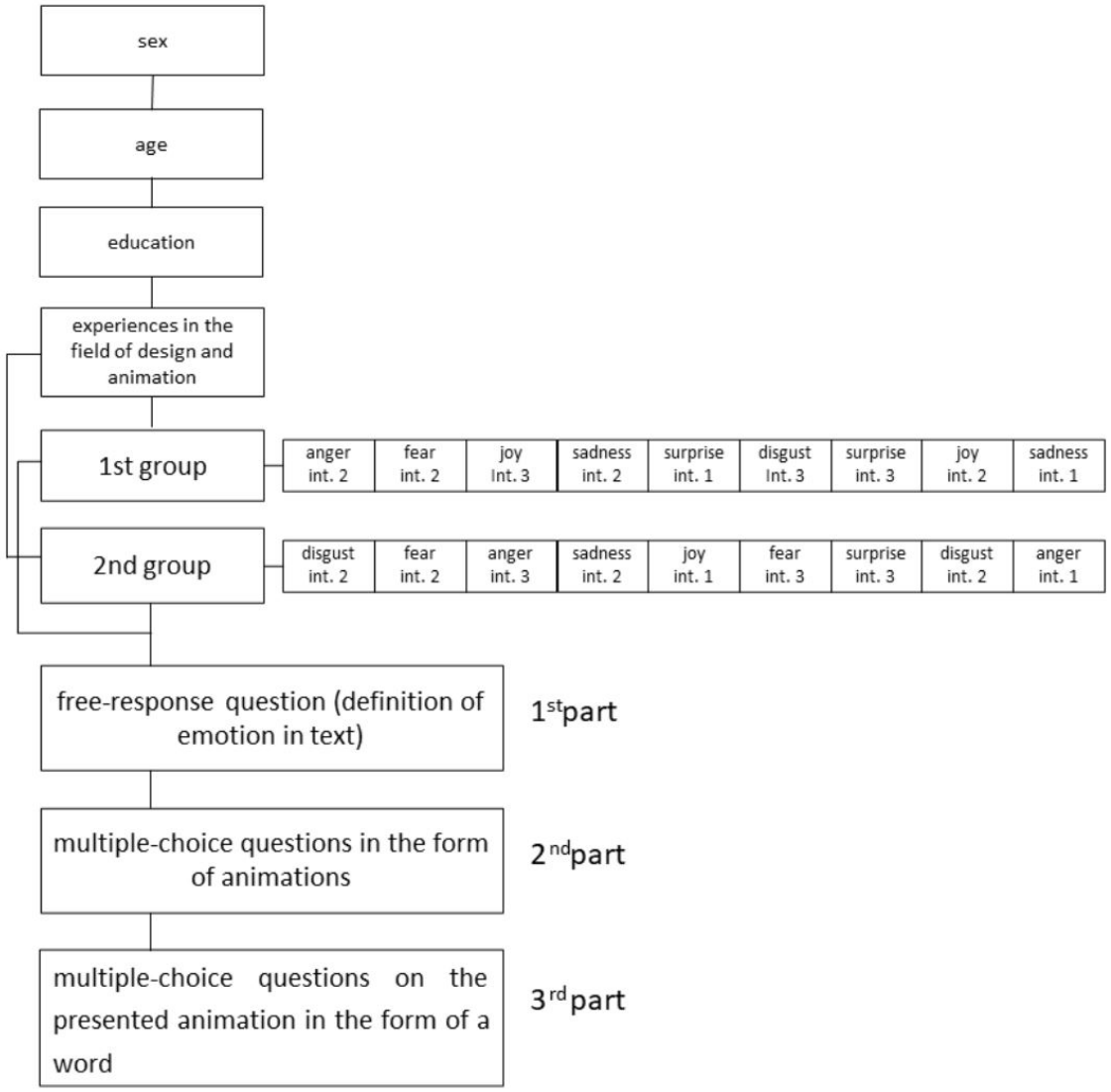
» **Figure 6:** *Display of character emotional expression in a loop*

Surveying

We designed the survey on the 1ka platform (https://www.1ka.si/d/sl). Respondents completed the survey via an online link that it was active for one month, from May 5th to June 5th, 2022, and was completed anonymously and voluntarily. Respondents answered the survey questions in their home environment or in the environment they were in when they answered the survey.

As shown in the organizational chart (Figure 7), the survey was structured to consist of three distinct parts.

Respondents could answer the survey in two ways, with random selection. One half of the selected emotion representations appeared in certain intensity for the first group of respondents, and the other half appeared in the second group of respondents, as indicated in the organisational chart.



» **Figure 7:** *The organizational chart shows sequence of survey questions for both groups of respondents (int. means intensity of indicated emotion)*

Experimental survey design

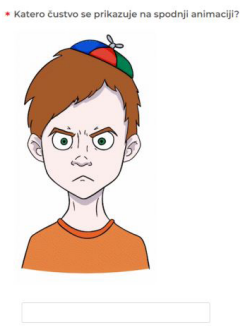
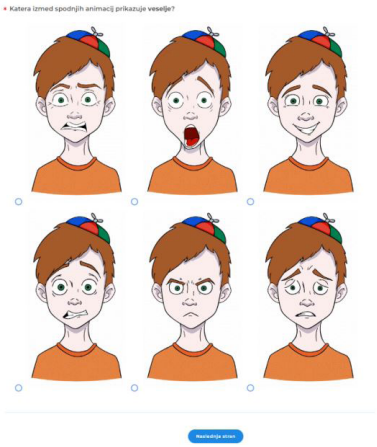
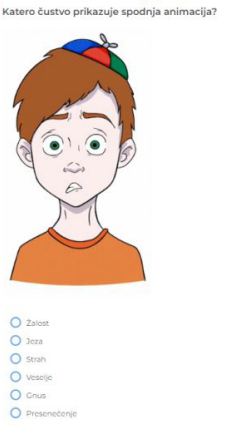
The survey was divided into a part to fill in general data (demographic data, previous experience with design and animation) and a part to evaluate and analyse the emotions depicted on the character (Figure 7). The latter was divided into three parts of analysis of animated emotions. The first part included free-response questions in which the respondents observed a single animation multiple times and then answered the question by writing what emotion they recognised, as shown in Table 1 (Part 1).

In this question, the viewers saw the animation for the first time and did not have previous experience of what the emotion is in the task. The second part consisted of a multiple-choice question with the answers presented in animations in which the viewers selected an animation presenting a particular emotion. The answers the respondents could choose were six different animations that were played until one was clicked and selected, as shown in Table 1 (Part 2).

The animations in the answer choices were different intensity representations of individual emotions and different emotions. The third and final part of the survey consisted of a word (term) choice as an answer, where the respondents answered the question with a selection of the term of which emotion was represented by the presented animation (Table 1, Part 3). In addition to the answers, the time the respondents needed to answer was also measured. We were able to calculate the solution time for each question from the metadata by placing each question in the survey on its own page, between which the viewer moved by clicking on the answer. When the viewer clicked on the answer, the time from when the page was displayed to when the viewer clicked on the answer was recorded in the metadata.

Table 1

Structure of survey questions: An example of a free question in a survey (Part 1), an example of choosing an answer among presented animations in a survey (Part 2), and an example of choosing an answer among selected written emotions in a survey (Part 3)

Survey's part	One	Two	Three
Questions' text	Free-response questions	Multiple-choice questions in the form of animations	Multiple-choice questions on the presented animation in the form of a word
	"Which emotion is shown in the animation below?"	"Which of the animations below shows joy?"	"Which emotion is shown in the animation below?"
Text and images of the questions			
Answer	Respondents typed an answer	Respondents clicked a selected image	Respondents selected one of the listed emotions: "sadness, anger, fear, joy, disgust, surprise"

Statistical analysis

The results were statistically analysed using a t-test for 95 % statistical reliability and a p-value of 0.05. We were interested in the statistical significance of the differences between the results for each emotion according to the responses to the questions, which asked respondents about the textual definition of the emotion (Part 1), the recognition of a particular emotion from the set of illustrations shown (Part 2), and the selection of the expression for the emotion next to the illustration shown, given some response options (Part 3).

We also statistically evaluated differences in the time it took respondents to recognise, define, and respond to emotions that were recognised.

Results and discussion

With the results of the survey, we determined the correctness of the recognition of individual emotions and the time spent by the respondents on the recognition itself. In total, 184 people started solving the survey, and 173 people completed it. From the results of the first question, it can be seen that many more women than men answered the survey, namely 140 women or 80 % and only 32 men or 18 %, while one of the respondents (2 %) described himself as undefined. The majority of respondents ticked the 19-25 age group, 100 people or 58 %, while a slightly smaller number of responses came from the 26-35 age group, 47 or 27 %.

The fewest responses came from the younger group up to 18 years of age, namely only 2 or 1 % of the responses, while there were slightly more responses from the older group over 36 years of age, namely 24 or 14 % of the responses. 105 or 61 % of the respondents had some prior experience in the visual arts, and 17 respondents or 10 % were involved in the visual arts as a hobby, and thus have little prior experience that can help them in their perceptions.

51 respondents, or 29 %, have never been involved with animation or character development and therefore have no prior experience to help with their perceptions.

Free-response questions

In response to the question "What emotion is shown in the following animation?" where the solving time was not yet measured, respondents answered as shown in Table 2. Under partially correct we counted all answers that did not contain exactly the right emotion but were still semantically correct, and under incorrect we recorded answers that were semantically incorrect. The best

Table 2

Table of correctness of perception of indicated emotion with average values and standard deviation from free-response question (where int. means intensity of indicated emotion)

Emotion	Int.	Correct [%]	Partly correct [%]	Incorrect [%]
Joy	1	18	17	65
	2	46	27	26
	3	61	13	26
	Aver.	41.7	19.0	39.0
	Std.	21.8	7.2	22.5
Sadness	1	56	34	10
	2	48	27	25
	3	97	2	1
	Aver.	67.0	21.0	12.0
	Std.	26.3	16.8	12.1
Surprise	1	36	54	10
	2	49	22	28
	3	27	47	26
	Aver.	37.3	41.0	21.3
	Std.	11.1	16.8	9.9
Anger	1	51	19	30
	2	88	7	6
	3	98	0	2
	Aver.	79.0	8.7	12.7
	Std.	24.8	9.6	15.1
Disgust	1	0	15	85
	2	5	18	76
	3	21	21	57
	Aver.	8.7	18.0	72.7
	Std.	11.0	3.0	14.3
Fear	1	5	12	83
	2	42	36	22
	3	38	2	59
	Aver.	28.3	16.7	54.7
	Std.	20.3	17.5	30.7

recognition of the emotion represented was found in the representation of sadness and anger at the highest intensity. Here, the correctness of the responses was up to 98 % for the representation of anger and 97 % for the representation of sadness. We noted a trend that Ekman has pointed out, namely that fear and surprise are often confused (Ekman, 1993). Regardless of the intensity of the representation, the worst recognition was obtained for the representation of disgust. Here we obtained 21 % correct responses at the highest intensity, 5 % at the medium intensity, and at the lowest intensity no one correctly recognized the emotion depicted. In the expression of disgust, we also noted the greatest dispersion of responses, as it was often replaced by fear, anxiety, anger, pain, surprise, nervousness, despair, and a variety of others (Ekman, 2003). For the representation of joy, as the intensity of the representation increased, so did the number of correct responses. For example, we had 18 % correct responses at the lowest intensity and 61 % correct responses at the highest intensity. At first glance, we could say that increasing the intensity of the expression of joy is a good thing, but among the incorrect answers, it turned out that many respondents associated the most intense expression of joy with discomfort and forced or false joy. From this we can conclude that an exaggerated display of joy does not pay off, as the viewer is more likely to perceive it as a bad, insincere emotion. A statistical analysis comparing the results for two-paired selected emotions (e.g., joy-sadness, joy-surprise, etc., for correct, partially correct, and incorrect responses) revealed that there were statistically significant differences for correct responses and recognition of the emotions in sadness and disgust ($p = 0.024$), surprise and disgust ($p = 0.033$), and anger and disgust ($p = 0.0108$). For the partially

correct responses, we confirmed a statistically reliable difference only in the results for recognition of the emotions surprise and anger ($p = 0.045$), and for the incorrect responses just as for the correct responses for the emotions sadness and disgust ($p = 0.005$), surprise and disgust ($p = 0.007$), and anger and disgust ($p = 0.008$).

Multiple-choice questions in the form of animations

In the 2nd part of the survey, respondents were asked the question, "Which of the following animations show _____?" and they could choose from six animations that showed all six emotions (joy, sadness, surprise, anger, disgust, and fear) at the same display intensity. The results are shown in Table 3. The last two rows of the Table 3 show the average value of the percentage of correct answers for each emotion with the standard deviation, and the last two columns show the average value of the time needed to answer for each emotion at the different intensities shown. The average values of the time required to recognize individual intensities with respect to the emotion with standard deviation are shown in Figure 8.

The best recognition of the emotion displayed at all intensities selected from the displayed animations of all emotions was observed on average for sadness, namely up to 95 % correct responses, at the lowest and medium intensities there were 93 % correct responses, and at the highest intensity of emotion display even 100 % correct responses. On average, the worst recognition

Table 3

Correctness of the recognition of the displayed emotion in percentage with average values and standard deviation for multiple-choice questions in the form of animations (int. means the intensity of the displayed emotion)

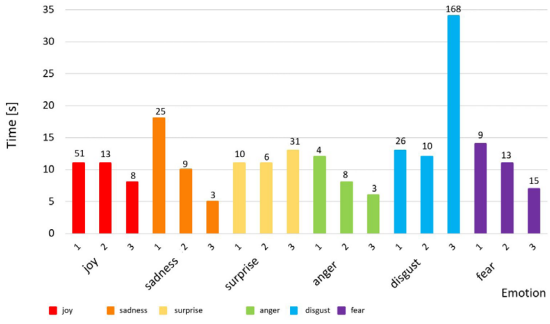
Emotion	Int.	Answers [%]					
		Joy	Sadness	Surprise	Anger	Disgust	Fear
Joy	1	88	2	2	4	5	0
	2	96	3	1	0	0	0
	3	100	0	0	0	0	0
	Aver.	94.7					
	Std.	6.1					
Sadness	1	1	93	0	0	3	3
	2	0	93	0	4	1	1
	3	0	100	0	0	0	0
	Aver.		95.3				
	Std.		4.0				
Surprise	1	1	0	92	1	1	4
	2	8	2	82	0	2	7
	3	1	5	92	0	0	1
	Aver.			88.7			
	Std.			5.8			
Anger	1	0	0	0	98	2	0
	2	1	0	0	90	9	0
	3	0	0	0	82	18	0
	Aver.				90.0		
	Std.				8.0		
Disgust	1	0	4	0	14	44	39
	2	0	8	3	3	66	19
	3	1	0	0	1	62	35
	Aver.					57.3	
	Std.					11.7	
Fear	1	5	3	8	0	11	72
	2	0	7	20	0	16	58
	3	0	0	15	3	8	73
	Aver.						67.7
	Std.						8.4

of the emotion displayed was observed at all intensities for disgust, namely 57 % correct. At the lowest intensity there were 44 % correct answers, at medium intensity there were 66 % correct answers and at the highest intensity of the emotion 62 % correct answers.

The best emotion recognition was obtained at the highest intensity of joy and sadness with 100 % correct answers, which means that of all the emotions presented, the respondents selected them the easiest and did not confuse them once with another emotion.

As can be seen in Table 3, recognition is successful for all intensities of joy, sadness, surprise, and anger, and slightly worse for recognition of disgust and fear.

In terms of time, respondents spent the least amount of time perceiving sadness at the highest intensity, i.e., only 5 seconds, while they spent the most time perceiving disgust at the highest intensity, i.e., 34 seconds, as seen in Figure 8. This is a very large time difference, which came about because the highest intensity of sadness has a very good indicator (tears) that is difficult to miss, and because, as we already know from the first part of the survey and from Ekman's research (Ekman, 2003), people rarely see disgust in real life and therefore it is more difficult to perceive during emotions. Figure 8 shows the average values of time with standard deviation assigned above the columns for the recognition of each emotion and its intensities in the survey's part with multiple-choice questions in the form of animations.



» **Figure 8:** *Emotion recognition (intensities 1-3) over time - mean values with standard deviation given in the numerical value above the column representing time (2nd part of the survey), No. of respondents = 173*

For the results of this part of the survey, statistical analysis of the results using the t-test revealed no statistically significant difference between the results of the responses with the choice of animation (for selecting a particular emotion). As well as the results of the time spent by the respondents to identify a particular emotion during the displayed emotions did not differ statistically significantly for the different animated emotions considered.

Multiple-choice questions on the presented animation in the form of a word

In the 3rd part of the survey, we asked the respondents the question "Which emotion does the animation below show?" and showed them the animation of the emotion, and they could choose from six text answers (joy, sadness, surprise, anger, disgust, and fear). In Table 4, we presented the results in percentage of answers the respondents needed to perceive each emotion at each display intensity.

The last two rows of Table 4 show the average value of the percentage of correct responses for each emotion with the standard deviation, and the last two columns show the average value of the time taken to respond for each emotion at the various intensities indicated. The average values of the time taken to recognize each intensity with respect to the emotion with standard deviation are shown in Figure 9.

The best recognition of the displayed emotion at all intensities, selected from the given responses of all emotions, was observed on average for anger, with an average of 94 % correct. At the lowest intensity there were 89 % correct responses, at medium intensity 98 %, and at the highest emotion intensity 96 % correct responses. It was expected that the recognition of anger would be quite high, since the eyebrows that were strongly characterized in the display of animation of this emotion are an important indicator of anger and supports correct emotion recognition.

On average, the worst recognition of the emotion presented was observed at all intensities for disgust, namely at the lowest intensity there were only 21 % correct answers and at medium and highest intensity 60 % correct answers. As we can see from the whole survey, disgust is generally perceived worse than other emotions, which was to be expected. It was found that the lowest intensity of disgust is perceived worst, as it was also discovered in the previous sets of questions.

In Table 4, the recognition is successful and high in numbers for all intensities of joy, sadness, surprise, and anger, and slightly worse for the recognition of disgust and fear. This is very similar to the table of recognition results from the previous set of questions (2nd part) in the survey.

A much larger difference can be seen in the confusion caused by incorrect answers. At first glance, it can be seen that the responses are not as consistent as in the previous set.

Here, respondents did not have the opportunity to compare with other animations, which we assume made it a little harder to identify the emotion.

Table 4

Correctness of the recognition of the displayed emotion in percentage with average values and standard deviation for multiple-choice questions on the presented animation in the form of a word (int. means the intensity of the displayed emotion)

Emotion	Int.	Answers [%]					
		Joy	Sadness	Surprise	Anger	Disgust	Fear
Joy	1	62	17	11	0	0	10
	2	95	0	5	0	0	0
	3	88	0	12	0	0	0
	Aver.	81.7					
	Std.	17.4					
Sadness	1	0	98	0	2	0	0
	2	0	72	0	0	16	12
	3	0	97	0	0	1	1
	Aver.		89.0				
	Std.		14.7				
Surprise	1	0	0	100	0	0	0
	2	0	0	83	3	1	13
	3	0	0	91	0	0	9
	Aver.			91.3			
	Std.			8.5			
Anger	1	0	3	3	89	3	3
	2	0	0	0	98	2	0
	3	0	1	3	96	0	0
	Aver.				94.3		
	Std.				4.7		
Disgust	1	8	15	18	10	21	29
	2	0	3	3	4	60	31
	3	0	2	2	28	60	9
	Aver.					47.0	
	Std.					22.5	
Fear	1	1	3	46	0	13	38
	2	0	0	21	0	26	53
	3	1	7	3	0	24	65
	Aver.						52.0
	Std.						13.5

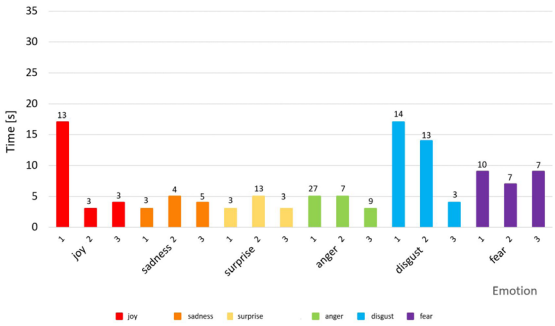
In terms of time spent, respondents spent much less time responding in this part of the survey than in the previous part 2 of the survey.

The least amount of time was spent perceiving sadness and surprise at the lowest intensity, joy at medium intensity, and surprise and anger at the highest intensity; otherwise, respondents took only 3 seconds to perceive them. Decision making took the longest at the lowest intensity of disgust and joy, 17 seconds, as shown in Figure 9.

Figure 9 shows the average values of time with standard deviation assigned above the columns for the recognition of each emotion and its intensities in the survey's part with multiple-choice questions on the presented animation in the form of a word. Statistical analysis and comparison of results from Table 4 revealed, that we cannot claim with statistical confidence that the differences are in the response patterns of respondents who chose among multiple emotion response options based on the animated emotion displayed. T-tests revealed no statistically significant differences.

The situation was somewhat different with regard to the time (Figure 9) spent by the subjects on the responses to each emotion.

Namely the t-test showed that there were significant differences in the results of the animated emotions sadness- anger ($p = 0.008$), surprise - fear ($p = 0.008$), and anger- fear ($p = 0.013$).



» **Figure 9:** *Emotion recognition (intensities 1-3) over time - average values with standard deviation given in the numerical value above the column representing time (3rd part of the survey), No. of respondents = 173*

Comparative analysis of the 1st- 3rd part survey results

On average, the emotion that was the most difficult to recognise and perceive was disgust, as shown in Table 5, as it was correctly perceived by only 38 % on average across all tasks, all intensities in survey parts 1st-3rd. At the lowest intensity, only 22 % correctly recognised it on average, 44 % at medium intensity, and 48 % at the highest intensity. This shows that the most difficult emotion to perceive was the lowest intensity of disgust. As for testing a statistically reliable difference in the recognition time of this emotion compared to other emotions, we can confirm the results only in the first part of the analysis, in which the respondents defined the emotions with free choice word. As mentioned above statistically significant differences in analysis of results of survey sets were found only in the case of disgust and the emotions sadness, surprise, and anger. On average, anger was the easiest emotion to perceive and was perceived correctly by respondents across all survey sets and all intensities at an average of 88 %. At the lowest intensity, it was correctly perceived 79 % of the time on average, and 92 % of the time at the medium and highest intensities. This shows that the emotions of medium and highest intensity of anger were the easiest to perceive. Statistical analysis confirmed a significant difference in the recognition time of anger only in part 3 of the survey, in which respondents defined the displayed animated emotion based on some given word answers for emotions presented in animation. The statistical analysis showed that on average of all answer sets only the recognition of anger and disgust differed statistically significantly with p = 0.031, whereas this cannot be claimed with statistical certainty for the comparison of the other emotion representations.

At the same time, the statistical analysis has also shown that the claim that the average values of the results of the correct answers of the three sets of surveys are different for different intensities of the emotions represented in the animation is confirmed only for the differences between the intensities of the emotions represented 1 and 2 (minimum and medium intensity) with the value p = 0.0106 and 1 and 3 (minimum and maximum intensity) with the value p = 0.0214, while the statistics have not confirmed the statistical significance of the difference between the answers for the intensity of the emotions represented 2 and 3 (medium and maximum intensity).

Table 5

Average values of correct recognition answers in survey's part 1st-3rd with standard deviation

Emotion	Survey part	Part's average [%]	Overall average [%] - part	Std.
Joy	1	42	73	27.6
	2	95		
	3	82		
Sadness	1	67	84	14.7
	2	95		
	3	89		
Surprise	1	37	72	30.6
	2	89		
	3	91		
Anger	1	79	88	7.8
	2	90		
	3	94		
Disgust	1	9	38	25.3
	2	57		
	3	47		
Fear	1	28	55	23.1
	2	68		
	3	68		

From the results and as it was expected, it is clear that previous experience of emotion recognition is very important for further perception, as there are large differences between the survey groups. The first survey's part, where the respondents had no previous experience, has the lowest percentage of correct answers, 44 %. The second and third parts, where respondents have already gotten a feel for our animations, have a higher percentage of correct answers, 82 % and 79 %, respectively. When we compare the average of the correctness of the parts (with different type of answers), we can also see that the second part has the highest percentage of correct answers, which tells us that our respondents generally perceive emotions better when the animations are next to each other and therefore choose the correct one. In actual communication, the recognition of emotions also occurs contextually according to the change in the expression of emotions in the face of the observed person (Boucher & Ekman, 1975).

In terms of time, on average, respondents solved the third part of the survey much faster than the second, as

the fastest solving time in the second part was 5 seconds and in the third part was 3 seconds, while the longest time was 34 seconds in the second part and 17 seconds in the third part. It has to be emphasised that faster solving does not mean more correct answers. In our opinion it does mean that respondents were much more decisive with their choices when they had all the animations in front of them and were choosing between words, even though the choices may not have been correct.

Statistically, we can confirm the differences in the correctness of responses in 1st part (when respondents saw animated emotions for the first time) and 2nd part of the survey (when they already had the experience of recognizing emotions and the chosen style of animation) with a value of p= 0.000025 and 1st part and 3rd part of the survey with a p value of p=0.0008, while there were no statistically significant differences between survey parts 2 and 3.

From our research results, for better recognition, we should exaggerate the most or show joy, sadness, disgust and fear the most intensely. Additionally, we could animate surprise and anger less intensely because we got the highest percentage of correct answers for them at lower intensities. In some respects, this correlates with the theory that anger, sadness, and joy are usually strongly emphasized in animations. However, it always depends on the story, the additional information, the environment, the animation style, and the personality of the animated character.

Conclusions

The results can be summarized in some guidelines that can help animators plan and design micro-animations of characters' faces. In the case of joy, we found that the percentage of correct recognition increases with the intensity of the representation. Consequently, we recommend to exaggerate with the representation of joy, however to be careful not to reach the point where this emotion seems fake, as some of our respondents wrote. In the case of sadness, we found that the emotion is best perceived at the highest intensity of the display, but the recognition is also good at the lowest intensity, so it is not necessary to exaggerate in sadness, since the lowest intensity is also very well perceived. In the case of the emotion surprise, we found that the percentage of correct recognition decreases with the intensity of the display, so exaggeration is not necessary in the case of surprise (we get good recognition at the lowest intensity). Our recommendation is not to exaggerate with animating surprise, as the viewer might confuse surprise with a completely different emotion, fear. In the case of anger, we found from the results that the percentage of correct recognition increases with the intensity of the representation, but the medium and maximum intensities are similar in recognition, while the minimum intensity is also high. Thus, in the representation of anger, it is not so crucial to exaggerate with micro-animation, since the minimum and maximum intensities were recognised well. For disgust, we found from the results that the percentage of correct recognition increases with the intensity of the representation of the emotion. We suggest exaggerating the animation of disgust, but to be careful as our research revealed that the overall percentage of recognition for disgust is very low. Animators should be attentive when depicting disgust so that it is as different as possible from surprise, otherwise viewers might confuse the presentation of these emotions. In the case of fear, which overall recognition was very low, we found that the percentage of correct recognition increases with the intensity of the representation. It can be deduced that the exaggeration of fear could benefit the representation of this emotion in animation.

Based on what has been written, below we also provide conclusions regarding the set hypotheses.

H1: The hypothesis was not confirmed, since most emotions, namely joy, sadness, anger, disgust and fear, were better perceived in the most intense representations. The only emotion that contradicted this was surprise, where the best recognition on average occurred for the least intense presentation of the emotion.

H2: The hypothesis was not confirmed. At the most intense representation of sadness, respondents correctly perceived 98 % of the emotion on average, the most of all. However, even for less intense representations, the percentages of correct recognitions are quite high.

H3: This hypothesis could be confirmed, as it proved to be true for anger but not for joy. In the case of joy, the percentage of correct responses for the lowest intensity of the emotion is quite low, 56 %.

H4: The hypothesis was not confirmed, as respondents in the third set perceived the medium intensity of joy the fastest (3 seconds) but took the longest to perceive the lowest intensity of joy (17 seconds). In contrast, in the second group, there was no joy in either the fastest or slowest recognitions.

H5: We refuted the hypothesis, as the respondents perceived sadness relatively quickly in the second group and took 3 seconds to perceive the lowest intensity, 5 seconds to perceive the middle intensity, and 4 seconds to perceive the highest intensity in the third group.

H6: The hypothesis could not be confirmed. In the second series of surveys, respondents perceived the most intense emotion faster for joy, sadness, anger, and fear, but not for surprise and disgust, where they perceived the lower intensity of the emotion pre-

sented faster. In the third series of surveys, respondents perceived the most intense emotion faster for anger and disgust, while they perceived the lower intensity emotion faster for the other emotions.

As authors of the study, we know that the study has some shortcomings so that the results cannot be generalized to the whole field of micro-animation planning of emotional expressions of animated characters. Only one character and one author's style in both illustration and animation were analysed. Drawing and analysing more characters and more illustration and animation styles would certainly expand the applicability of the results and guidelines. This is also the goal of further research. The character was otherwise designed neutrally, and the findings of important research in the field of emotion recognition were included in the illustrations of the intensity of animated emotions. Notwithstanding these limitations, we believe that the research results provide useful guidelines for planning work in the field of animation and a useful systematic account of experimental design analysis of the effects of the design of facial expressions of animated characters on emotion recognition.

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