PERCEPTION OF MICRO-EXPRESSIONS IN ANIMATED CHARACTERS WITH DIFFERENT VISUAL STYLES

by

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ABSTRACT

The purpose of this research was to examine the perception of micro-expressions in animated characters with different visual styles. Specifically, the work reported in this thesis sought to examine: (1) whether people can recognize micro-expressions in animated characters, (2) whether there are differences in recognition based on the character visual style (stylized versus realistic), (3) the extent to which the degree of exaggeration of micro-expressions affect the perceived naturalness and intensity of the animated characters' emotion, and (4) whether there are differences in effects on perceived naturalness and intensity based on the character visual style. The research work involved two experiments: a recognition study and an emotion rating study. A total of 275 participants participated in both experiments. In the recognition study, the participants watched eight micro-expression animations representing four different emotions (happy, sad, fear, surprised). Four animations featured a stylized character and four a realistic character. For each animation, subjects were asked to identify the character's emotion conveyed by the micro-expression. Results showed that all four emotions for both characters were recognized with an acceptable degree of accuracy. The recognition rates of the stylized character were 84.73% for happiness, 88.73% for sadness, 60.73% for fear, and 83.64% surprise. The recognition rates of the realistic character were 87.37% for happiness, 82.94% for sadness, 69.62% for fear, and 77.13% for surprise. In the emotion rating study, participants watched two sets of eight animation clips (16 clips in total). Eight animations in each set featured the character performing both macro- and micro-expressions, the different between these two sets was the exaggeration degree of micro-expressions (normal vs exaggerated). Participants were asked to recognize the character's true emotion (conveyed by the micro-expressions) and rate the naturalness and intensity of the character's emotion in each clip using a 5-point Likert scale. Findings showed that the **degree of exaggeration of the micro-expressions** had a significant effect on **emotion's naturalness rating**, **emotion's intensity rating**, and **true emotion recognition** and the **character visual style** had a significant effect on emotion's **intensity rating**. Emotion type, participant gender and participant animation experience also had significant effects on perception of the micro-expression.

CHAPTER 1 INTRODUCTION

1.1 Introduction

This chapter presents a brief overview of this research and provides basic information of the problem and purpose statement, scope, research questions, significance, definition of terms/concepts, assumptions, limitations, and delimitations.

1.2 Problem and Purpose Statement

The problem addressed by this research is that researchers do not have enough knowledge on whether micro-expressions, one important way to convey human hidden emotions, have an effect on perceived naturalness and intensity of 3D animated characters' emotions. Several prior studies have examined recognition of micro-expressions in humans. Ekman & Friesen (1974) developed a test called the brief affect recognition test (BART). One of the six basic emotions (happiness, surprise, disgust, anger, fear, and sadness) was presented from 40ms to 300ms. Shen et al. (2012), used BART to measure a person's ability to recognize micro-expressions. Ekman (2003) developed another tool called micro-expressions training tool (METT), which presented a micro-expression between two neutral expressions. Pfister et al. (2011) developed a framework, in which they used "temporal interpolation to counter short video lengths, spatiotemporal local texture descriptors to handle dynamic features and {Multiple Kernel Learning and Random Forest} to perform classification" (Pfister et al., 2011). The framework successfully recognized the spontaneous micro-expressions, and the system matched the micro-expressions recognition accuracy of not only a 100fps camera, but also a 25fps standard camera.

One study examined the recognition of micro-expressions in computer graphics animated faces (Queiroz & Muzz, 2014). The researchers reported that the presence of an opposite normal emotion does not affect the recognition of micro-expressions and people can recognize micro-expressions in the virtual world. But, to the best of the researcher's knowledge, no prior studies have tested the effect of visual style on recognition of micro-expressions in animated characters and the effect of exaggeration of micro-expressions on perceived emotion's naturalness and intensity. The main goal of this research is to investigate the extent to which the degree of exaggeration of micro-expressions influences the naturalness and intensity of 3D animated

characters' emotion and whether the visual style of the characters (realistic versus stylized) affect recognition and perceived emotion's naturalness and intensity: More specifically, the research aims to answer four research questions:

- **RQ1**: Can viewers recognize animated character's micro-expressions?
- **RQ2**: To what extent does the animated character's visual style affect the recognition of micro-expressions?
- **RQ3**: To what extent does the degree of exaggeration of micro-expressions affect the perceived naturalness and intensity of the animated character's emotion?
- **RQ4**: To what extent does the visual style of 3D animated character affect the perceived naturalness and intensity of the animated character's emotion?

1.3 Scope

This research focused on the perception of micro-expressions in 3D animated characters and tested the accuracy of micro-expression's recognition.

It also focused on the influence of the degree of micro-expressions' exaggeration on the naturalness and intensity of 3D animated character's emotion and the effect of 3D animated character's visual style on the recognition of micro-expressions and on perceived emotion naturalness and intensity.

1.4 Significance

Why is a study on the influence of micro-expressions' degree of exaggeration on the naturalness and intensity of 3D animated agent's emotion useful? According to the literature reviews, emotional expressivity is one of the most important traits of a good actor. If an actor is immersed in the situation, he/she will show micro-expressions when emotion fluctuates. This standard also applies to 3D animation. Animation viewing experience is important to every audience. The audience wants to follow the character's emotional fluctuations. A good animation must provide this opportunity to the viewers. That is why the researcher believes micro-expressions are important in 3D animations.

Based on prior studies, micro-expressions have important effects on viewer's responses. For instance, Stewart et al.'s study (2009) "illustrates that the presence of facial micro-expressions

in political speeches affects emotional response to the speech" (p. 130). Research by Russell et al. (2006) suggests that patients with schizophrenia improved their emotion recognition with "micro-expressions training tool (METT)". Matsumoto and Hwang (2011) reported that retail employees improved their ability to read micro-expressions and improved socio-communicative skills after they trained with METT.

The overall goal is to design believable animated characters that can convey realistic, natural emotions through speech, facial expressions, and body gestures. Within the context of this goal, the specific objective of this thesis was to examine the extent to which the agents' facial micro-expressions affect viewers' perception of the agents' emotions and their naturalness.

Micro-expressions are very brief facial expressions that occur when a person either deliberately or unconsciously conceals an emotion being felt (Ekman & Friesen, 1969). The researcher's assumption is that if the animated agents display facial micro expressions in addition to macro expressions, they will convey higher expressive richness and naturalness to the viewer, as "the agents can possess two emotional streams, one based on interaction with the viewer and the other based on their own internal state, or situation" (Queiroz et al. 2014, p.2).

1.5 Definitions of Terms/Concepts

3D Animation - an art of using motion to bring characters, vehicles, props, and more to life within TV shows, films, and games. (Fitzgerald, 2018)

Naturalness of emotion –how realistic/natural is the emotion expressed by the character?

Intensity of emotion – the magnitude and strength of the emotion.

Close up shot – a type of camera shot size in film and television that adds emotion to a scene (MasterClass, 2020).

Facial Action Coding System (FACS) – it is a comprehensive, anatomically based system for describing all visually discernible facial movement (Facial Action Coding System, 2020).

Action Units (AUs) – individual components of muscle movement (Facial Action Coding System, 2020).

Micro-expression - is a kind of facial expression that occur within a fraction of a second. This involuntary emotional leakage exposes a person's true emotions. (Micro Expressions / Facial Expressions, 2020)

Macro-expression - is a normal facial expression which last between ½ to 4 seconds. It always matched with the content and tone.

Realistic 3D character - a kind of 3D model which is designed to be as real as a person.

Stylized 3D character - a design with modified or abstracted element that give the design a more decorative look. (Artlandia)

Universal micro-expressions (UME) - Happiness, fear, sadness, disgust, surprise, and anger.

1.6 Assumptions

This research assumes the followings to be true:

1. Participants will be able to view 3D animations.
2. Participants will be able to read and understand English, especially the questions provided in the tests.
3. Participant will be able to perceive facial expressions.
4. Participants will answer questions honestly.

1.7 Limitations

There are several limitations of this research:

1. Due to the Covid-19, the test will be online. Participants may not be exposed in same environment during the test. There might be other uncontrollable elements that will affect participants' recognition, such as internet problem, interaction with other people, etc.
2. Participants may not pay enough attention to the micro-expression in 3D animations. This may cause the data is biased.

1.8 Delimitations

The research is not considered the followings:

1. The research will be processed with a pre-determined period because of the expiration date.
2. The distribution of demographics may not be normal.

1.9 Chapter Summary

This chapter provides the basic information of this study including problem statement, purpose, research questions, significant, assumptions, definition of terms, limitations, and delimitations. The following chapter will provide the literature review relevant to the research.

CHAPTER 2 LITERATURE REVIEW

The literature review is organized around six themes, to address the research questions which were mentioned before. These themes are: character visual style, emotion, emotion recognition, character perceived naturalness and intensity of emotion, micro-expressions, macro-expressions, A concept map of the literature review is included in figure. 2.1.

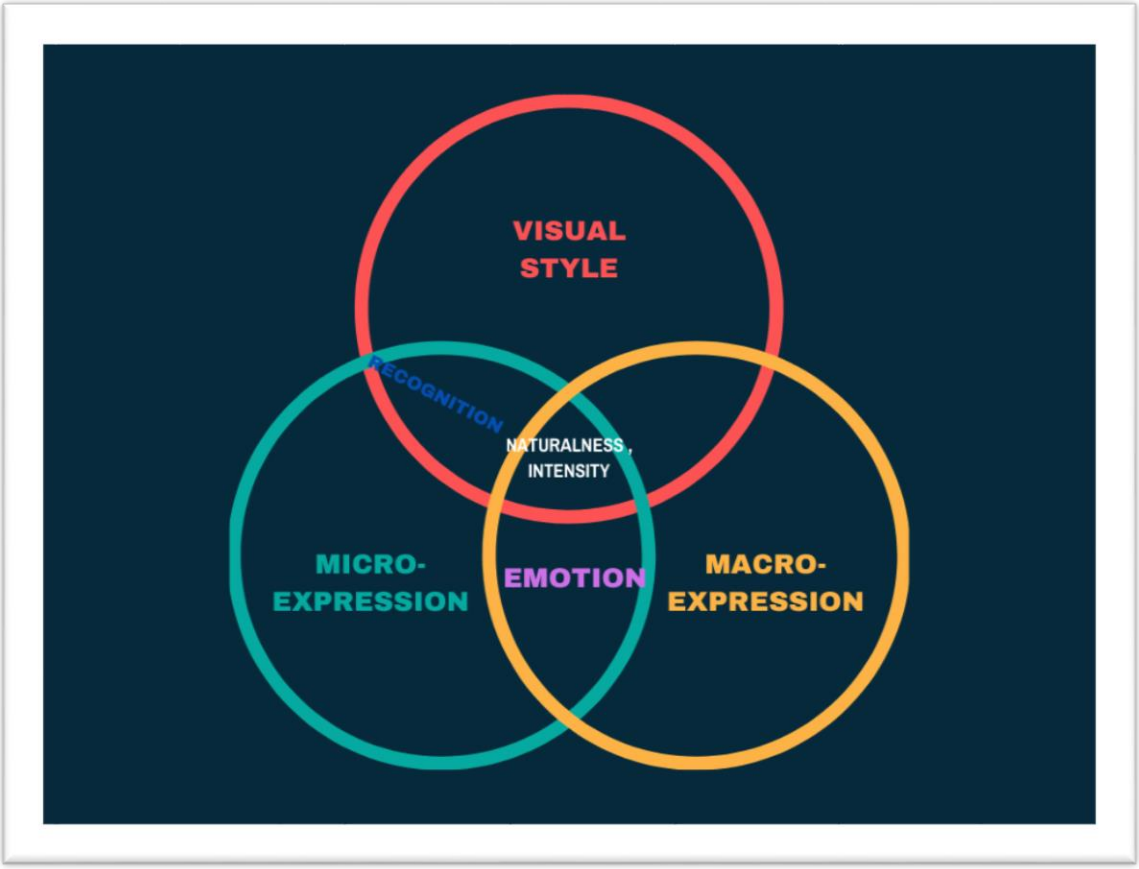


Figure 2.1 Concept Map of Literature Review

2.1 Methodology

The main background of this research is 3D animation. Narrowing down the main background, there are two important factors for the success of animation, emotion's naturalness and intensity, and emotion recognition. Visual style is another factor that is tested for the recognition of micro-

expression and emotion. In between micro-expression and macro-expression is emotion. The methodology of the literature review is shown in figure 2.1.

IEEE, Google Scholar and PsycINFO were the databases for searching for animation and psychology related sources. The keywords for searching were micro-expression, recognition, believability, and emotion.

2.2 Emotions: classification and expression

There are several systems for classification of emotions. Russell's (1980; 2003) model of core affect is useful for classifying emotional expressions which is based on two dimensions: valence (ranging from unpleasurable on the left to pleasurable on the right) and arousal (activation on the top to deactivation on the bottom). These two dimensions are further divided into four quadrants: 1) the upper-left quadrant represents high activation-displeasure, the typical emotion of which is frustration; 2) the upper-right quadrant represents high activation-pleasure, the typical emotion of which is happiness; 3) the lower-left quadrant represents deactivation-displeasure, the typical emotion of which is boredom; 4) and lastly, the lower-right quadrant represents deactivation-pleasure, the typical emotion of which is contentment. This model can cover a wide enough range of emotions as Russell (2003) mentions "core affect is primitive, universal, and simple [and] can exist without being labeled, interpreted, or attributed to any cause" (p. 148).

Ekman & Friesen (ref) identified six basic emotions conveyed by the human face, which are: happiness, sadness, surprise, fear, anger, and disgust. This conclusion was based on the analysis of observers who were asked to interpret what emotion they saw in human faces presented to them. Observers sometimes agreed when describing a specific face exhibiting the same emotion, but sometimes disagreed with each other when describing another face with same emotion. According to Ekman & Friesen (2003), "80 percent of the observers agree in describing a particular face with the word 'afraid' [but] might not agree about a word to describe some other face; for example, a face called 'disinterest'" (p. 21). Based on the results, Ekman & Friesen finally came up with their conclusion of the six basic expressions of human emotions previously mentioned. Although there may be other emotions that are conveyed in human expression, they have not yet been confirmed by an investigator. Ekman & Friesen (2003) mentioned that they would demonstrate how the six emotions typically appear on faces in addition to how the thirty-three distinct variations of these emotions present as the breadth of emotional expression is much larger

and nuanced (2003). The researcher decided to use Ekman & Friesen's model (2003) for the emotion classification in this study.

According to Jack, Sun, Delis, Garrod & Schyns (2016), "as a highly social species, humans generate complex facial expressions to communicate a diverse range of emotions" (p. 7241). However, do people express their emotions through facial expressions differently because of culture differences? Hoffman (2008) notes, "in the 1960s, many anthropologists thought that a smile could convey joy in one culture and disgust in another." But Ekman proved the previous statement was not correct in that it oversimplified the extent to which culture played a role in emotional expression. As Hoffman (2008) also mentions, "et when participants were asked to point to a pictured face that matched the emotion evoked by a particular story – anger, disgust, fear, joy, sadness or surprise – they made the same associations as people living elsewhere. There was one exception. The South Fore people did not distinguish between fear and surprise."

2.3 Micro-Expressions and Macro-Expressions Studies

Facial expression is one of the most important factors for emotion representation and perception. Zhang et al. (2018) mentioned the following: "Facial expression recruited faster and more accurate perception of emotional display and recruited more intense neural processing in the occipital-temporal network than vocal prosodies". This research proved facial expression can be more effective than speech when expressing emotion.

The term micro-expression was first coined officially by Paul Ekman and Wallace V. Friesen in 1969; Stephen Porter and Leanne ten Brinke (ref) confirmed the existence of micro expressions in 2008. Micro-expressions happen involuntarily or when someone is trying to hide and fake their emotion. For example, if policy officer is investigating a person who just stole something from a market, this person will try their best to hide fear emotion. The emotional clues that happen on their face when they are hiding fear, are called micro-expressions. So micro-expressions are an important way to reveal one's inner world and show hidden emotions. Based on this knowledge, the recognition of micro-expression is one of the key factors of this research. There are some previous studies that have researched micro-expression's recognition. According to Rehm and André (2005), they set up an experiment combining micro-expression with an opposite emotion, tested that can people recognize the conflict between true emotions and

emotions which was conveyed deliberately. The conclusion was people can notice the difference, which suggests that micro-expressions can be recognizable in virtual world.

A study by Stewart investigated the effect of micro-expression on viewer's emotion. Findings showed that viewer's emotion does change if he does not receive micro-expression. "Participant responses to removing the facial micro-expressions from the speech suggest that micro-expressions of facial affect do change emotional response. Participants became significantly more threatened and angry as a result of the speech with the micro-expressions removed" (Stewart et al., 2009, p. 130). It can be concluded that micro-expression's existence is crucial and necessary for human daily life.

According to Shen et al (2012), the duration of micro-expression had significant effects on micro-expression's recognition. They introduced two methods developed by Ekman to measure people's ability to recognize micro-expressions, which are brief affect recognition test (BART), and micro-expression training tool (METT). The difference between BART and METT is, METT presents micro-expression between two neutral expressions, but BART does not. Shen et al (2012) cited following: "According to Matsumoto et al. (2000), this test (BART) has the drawback of producing afterimages that affect judgments and reduce the ecological validity of the test (it is unlike real life because there are no preceding or following expressions)". They conclude that 160ms duration or above is stabilized for audience to recognize, and the accuracy of micro-expression's recognition differs a lot between BART and METT especially at short durations (40ms – 160ms). And based on the definition of micro-expression, the total duration should be less than 500ms. According to Yan et al (2013), they gave a definition of onset duration which should be less than 260ms.

2.4 Emotion Recognition from facial expressions

Facial expressions are crucial for the recognition of emotions and it were defined as "rapid". Several approaches have been developed to detect facial emotions. Ekman & Friesen (1978) developed the Facial Action Coding System (FACS), a system based on anatomy, to detect and encode facial muscle movement and find a particular emotion. With the improvement of technology, Pardas & Bonafonte (2002) used active contours to detect facial expressions automatically.

Mase (1991) who was the first one to bring image processing techniques into the recognition of facial expressions, developed an emotion recognition system that uses optical flow to evaluate facial muscle movements. In the system, never impulses trigger the facial muscle motion which caused the deformation of facial skin. The system was successfully built because facial skin is a fine-grained organ, which helps extract the optical flow. Finally, classification experiments showed an accuracy with 80% of 4 emotions' recognition: happiness, anger, disgust, and surprise.

McDonnel et al. (2008) examined the perception of 6 basic emotions from the movements of a human actor and from the same movements of 5 virtual characters. They concluded that the character's visual style does not affect the viewer's perception of emotions from body movement and facial movement. Another study by Cissel (2015) showed that character body study does not affect recognition of facial emotions significantly.

2.5 Emotion's Intensity and Naturalness Studies

Estimating the intensity of emotion from animations and human behavior is important. Adamo Nicoletta et al. (2019) gave a good definition of emotion's intensity, "how well does the character facial emotion strength match that of a human facial emotion strength?".

Thuseethan et al. (2019) proposed a metric-based approach for definition of emotion's intensity level. They used a 5-point scale range from 1-5 (1 = low, 5 = high) for representing the intensity of each dominating facial AU. For example, the only dominating AU for "happiness" was AU12 (Lip Corner Puller), and the intensity range for "happiness" was from 1 (1x1) -5 (5x1). The dominating AUs for "fear" were AU1 (Inner Brow Raiser), AU2 (Outer Brow Raiser), and AU4 (Brow Lowerer). Therefore, the intensity range for "fear" was from 3 (1x3) – 15 (5x3). They used a deep hybrid convolutional neural network (CNN) – based architecture for emotion intensity classifying. One interesting finding was that the emotion with low intensity classes (e.g., happiness) had rather higher recognition accuracy and the emotion with high intensity classes (e.g., fear) had rather lower recognition accuracy.

Naturalness is another important factor of emotion, and it can be referred as how realistic/natural is the emotion expressed by the agent?

According to Sato & Yoshikawa (2004), they examined the effect of velocity and emotion on the naturalness rating of facial expressions in 3D animations. The result showed that at

40ms/frame, sadness was rated with significant higher naturalness rating than surprise, anger, happiness, and disgust, but was rated significantly lower natural than fear. Another interesting finding was that all emotions had negative relationship between naturalness and velocity except sadness.

2.6 Character Visual Style Studies

Visual style is another important factor for facial expressions' recognition. Welch et al. (1996) mentioned that presence and audience involvement was enhanced by pictorial realism (Welch et al., 1996). Also, McCloud summarized the notion that conveying ideas through cartoon icons is more effective than photo realism. There were several reasons for this, the first was photos contained more details than stylized sketches and this caused more distraction. The next reason was, "thoughts and ideas likewise exist mainly as vaguely sketched forms" (McCloud, 1998). Hyde, Carter, Kiesler & Hodgins (2016) notes that animated characters display a wide array of personality characteristics to provide fulfillment for social roles. Facial motions play a role in perpetuating emotional expression through cartoon icons effectively (Hyde et al, 2016).

Adamo-Villani, Lestina & Anasingaraju (2016) conducted a study with two polygonal characters with different visual styles, which include realistic and stylized. In better understanding the way that avatars are perceived, the study looked at the way American Sign Language is used to enhance recognition and appeal to audiences. Adamo-Villani et al (2016), found that "while character's visual style does not have an effect on subjects' perceived legibility of the signs and sign recognition." The stylized approach to the animated character was more appealing than the realistic option.

Additional research finished by McDonnell et al in 2008 reported that cartoon characters were rated as higher appealing and more friendly than realistic characters. But they also mentioned "our results indicate that when realistic human body motion is used, it is the motion and not the body representation that dominates our perception of portrayed emotion" (McDonnell et al., 2008). When too much ambiguity is present, it makes it harder for humans to identify with the motion or the stimuli in question (Van Marlen, Van Wermeskerken & Van Gog, 2018). Based on this result, it means even stylized characters can be more appealing to audience, but the visual style is not the main factor of emotion perception. Abraham (2009) notes that cartoons may be used as a visual mode of communication. As such, emotional perception should be a point of consideration in the

extent to which this medium is believable. De Borst & De Gelder (2015) take it a step further by underscoring the notion that "expressions of emotions in human-like avatars can be perceived similarly to human emotions, with corresponding behavioral, physiological and neuronal activations, with exception of physical dissimilarities" (p. 576). Grewe, Liu, Kahl, Hilderbrandt & Zachow (2021) suggest that realistic faces can sometimes have an unexpected impact on the audience, which further suggests future research in the implications of character visual styles in the context of believability.

2.7 Summary

Chapter 2 gives a theoretical basis for the study and clarifies relevant concepts. This chapter demonstrates the methodology of the literature review and research method.

CHAPTER 3 METHODOLOGY

3.1 Introduction

This chapter reports the methodology used in this research. It is composed of four sections Methodology and Framework, Stimuli and Experimental Instrument, Recognition Study, Emotion Rating Study.

3.2 Methodology and Framework

There is a scarcity of research on the perception of micro-expressions in animated characters. In particular, to the researcher's knowledge, no prior studies have examined the effect of the degree of exaggeration of micro-expressions on the perceived naturalness and intensity of 3D animated characters' emotions and the extent to which the character's visual style affects the recognition of micro-expression and the perceived naturalness and intensity of the character's emotions. The work reported in this thesis aimed to fill this gap. The researcher created three groups of 3D animations, each group featuring two characters with different visual styles (stylized and realistic).

The first group of animations contained micro-expressions only and this group was for testing recognition of micro-expressions. The second and third group of animations contain both macro- and micro-expressions. The degree of exaggeration of micro-expressions was normal in group 2 and was exaggerated in group 3. The participants were asked to recognize the emotion and rate the emotion's naturalness and intensity for each clip in these two groups. A total of 275 participants joined the study.

3.3 Stimuli and Evaluation Instrument

The researcher used "MAYA 2019" software and two characters downloaded from internet sources to develop the 3D animations. One character is stylized and the other one is realistic. They are shown in figure 3.1.

Figure 3.1 Realistic Character (left) and Stylized Character (right)

The two characters (realistic and stylized) applied in the research were rigged with identical facial skeletal deformation systems. According to Adamo's research, the facial skeleton, comprised of 30 floating joints with 55 DOF, is based on best practices in character animation, on the Facial Action Coding System (Adamo et al., 2019).

There are 15 articulators of the skeletal joints: Both Lips, Cheeks, Chin, Ears, Eyebrows, Eye gaze, Head, Lip Corners, Lower Lips, Lower Eyelids, Nose, Teeth, Tongue, Upper Eyelids, Upper Lips. The researcher rotated or translated with 1 or more joints to move the facial muscle. The researcher animated the emotion based on FACS. Figure 3.2 shows that the AU and Head Movement had been used for each emotion.

Emotion	AU	Head
Happy	1(Inner Brow Raiser) + 2(Outer Brow Raiser)+ 6(Cheek Raiser) + 12(Lip Corner Puller)	53(Head Up)
Sad	1(Inner Brow Raiser)+ 4(Brow Lowerer)+ 15(Lip Corner Depressor)+ 17(Chin Raiser)	54(Head Down)
Fear	1(Inner Brow Raiser) + 2(Outer Brow Raiser) + 4(Brow Lowerer) + 5(Upper Lid Raiser) + 7(Lid Tightener) + 20(Lip Stretcher) + 26(Jaw Drop)	53 (Head Up)
Surprise	1(Inner Brow Raiser) + 2(Outer Brow Raiser)+ 5(Upper Lid Raiser) + 26(Jaw Drop)	57(Head Forward)

Figure 3.2 AU and Head Movement for each Emotion

As previously mentioned, the researcher created three groups of 3D animations. The first group of animations was used to test the accuracy of micro-expression's recognition. Each animation in this group demonstrated one of Ekman's emotions (happy, sad, surprise, and fear) shown in figure 3.2, and only contained micro-expression. The researcher used the METT (ref),

e.g., the micro-expression was presented between two neutral expressions and lasted 208ms. The participants were asked to select the emotion conveyed by the character.

Figure 3.3 Four emotions (fear, happy, sad, and surprise) displayed by the two characters

Then, the researcher developed another set of eight 3D animations with the same emotions which contained both macro-expression (emotion1) and normal (e.g., non-exaggerated) micro-expression (emotion2). Participants were asked to rate the naturalness and intensity of the 3D animated character's emotion and recognize the character's true emotion (conveyed by the micro-expression). After that, another eight animations were created with macro-expression (emotion1) and exaggerated micro-expression (emotion2), the participants were asked to rate the naturalness and intensity of the 3D animated character's emotion and recognize the character's true emotion (conveyed by the micro-expression).

There were 24 animations[1] shown in this research. The animations in micro-expression's recognition study were 1.55s long with a frame rate of 24fps. The structure of the animations was: neutral face – micro-expression – neutral face. The animations in emotion rating study were 3.29s long with a frame rate of 24fps. The structure of the animations was: neutral face – macro-expression (emotion1) – normal/exaggerated micro-expression (emotion2) – neutral face. All the animations were rendered with the resolution of 1920x1080 pixels and exported as QuickTime format. Twelve animations featured the realistic character (3 for each of the 4 emotions), and twelve animations featured the stylized character (3 for each of the 4 emotions). All animations do

[1] https://purdue.ca1.qualtrics.com/jfe/form/SV_6mpCSL06pPfnyqG

not include any sound and framed with same camera angle and lighting effect. The researcher edited the curve in graph editor in "MAYA 2019" to keep the flow of animation same.

3.4 Recognition Study

A recognition study was performed to test whether people could recognize the emotions conveyed by the micro expressions (in isolation). The stimuli included eight 3D animations created by the researcher.

3.4.1 Sample and Variables of the Recognition Study

275 participants were recruited by the researcher by sending emails to his friends, relatives, and classmates. The researcher also asked a CGT professor to send the study survey link to her students.

The independent variables of the recognition study were **emotion type** and **character's visual style**. The dependent variable of the recognition study was **recognition of micro-expression.**

3.4.2 Procedure

The questionnaire is shown in figure 3.4. Participants were asked to watch eight animations with four animations featuring the realistic character and four animations featuring the stylized character. Each character displayed four of the six basic emotions (happy, sad, fear, surprise) by micro-expression. Then participants were asked to recognize which emotion the character in the animation expressed. The data was collected in the form of correct/incorrect answers to questions. The questionnaire was designed to validate the recognition rate of micro-expression in 3D animation. Limbrecht et al. (2012) reported that emotion recognition rates above 55% can be chosen for further analysis. The baseline acceptable recognition rate was set to 60% in this study.

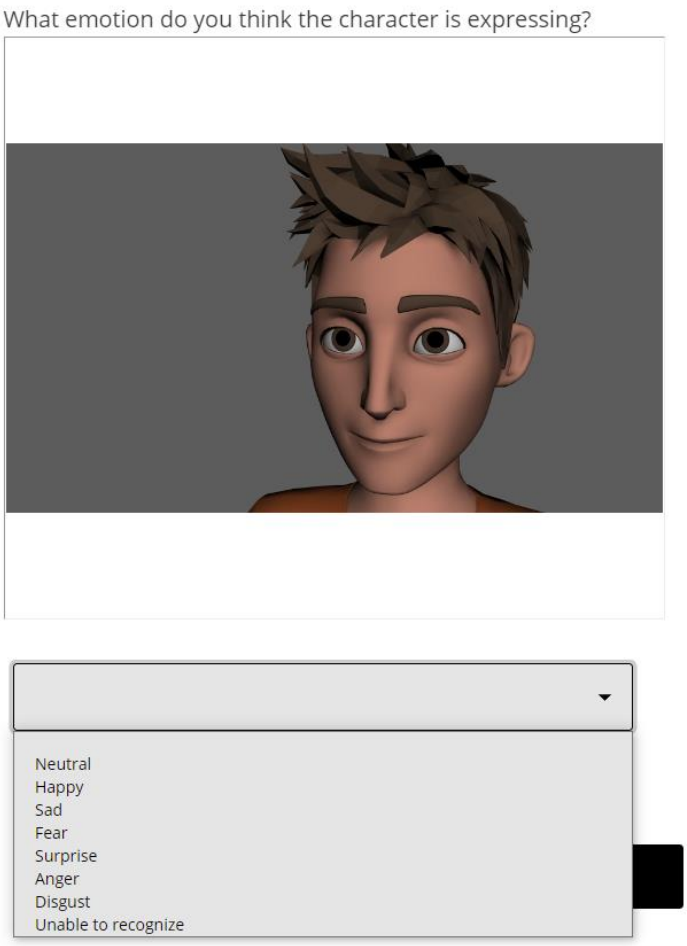


Figure 3.4 Screenshot of Questionnaire

3.5 Emotion Rating Study

The emotion rating study examined the extent to which visual style of an animated agent (realistic to stylized) affects the naturalness and intensity of the agent's emotion. The study used a within subject design and a quantitative research approach. Data was collected in the form of answers to rating questions, which asked participants to rate the naturalness and intensity of the emotions showed by the animated characters from scale 1-5 (1=low and 5=high). The study also collected the data in the form of correct/incorrect answers to questions, which asked participants to select the emotion that they think the character is truly feeling.

The independent variables in this study were the **3D animated character visual style** (realistic versus stylized) and the **degree of exaggeration of micro-expression** (normal/exaggerated), the dependent variables were **true emotion recognition**, **rating of naturalness**, and **rating of intensity**.

3.5.1 Hypotheses

- **H1(0)**: Viewers can recognize animated character's micro-expressions effectively.
- **H1(1)**: Viewers can not recognize animated character's micro-expressions effectively.
- **H2(0)**: Animated character's visual style affects viewer's recognition of micro-expressions.
- **H2(1)**: Animated character's visual style does not affect viewer's recognition of micro-expressions.
- **H3(0)**: The exaggerated micro-expressions affect the perceived naturalness and intensity of 3D animated character's emotion.
- **H3(1)**: The exaggerated micro-expressions do not affect the perceived naturalness and intensity of 3D animated character's emotion.
- **H4(0)**: Animated character's visual style affect the naturalness and intensity of the character's emotion.
- **H4(1)**: Animated character's visual style does not affect the naturalness and intensity of the character's emotion.

3.5.2 Sample of the Emotion Rating Study

Participants were found by the researcher sending emails to his friends, relatives, and classmates. And the researcher asked a CGT professor to send the survey link to her students. A total of 275 participants joined the validation study eventually.

3.5.3 Flow of the Emotion Rating Study

At the very beginning of each questionnaire, there was an introduction about the term of "naturalness" and "intensity".

- **Naturalness** refers to, how realistic/natural is the emotion expressed by the character?
- **Intensity** refers to, the magnitude and strength of the emotion

Participants were asked to watch two groups of animations. Each group contained 8 animations. After the participants watched all 8 animations (4 emotions of realistic character, 4 emotions of stylized character) in group 1, they were asked to rate the naturalness and intensity of the character's emotion using a scale from 1-5. They were also asked to select the true emotion that the character tried to hide with macro-expression but revealed with micro-expression. After they watched all the animations in group 1 and answered all the questions. They were asked to watch 8 animations (4 emotions of realistic character, 4 emotions of stylized character) in group 2. They were also asked to select the concealed emotion and rated the naturalness and intensity of the character's emotion.

3.7 Chapter Summary

This chapter summarizes the methodology and framework of the research, shows the test flow, explains the population, samples, variables, and experimental instrument of this research. This chapter also explicates the stimuli of the research.

CHAPTER 4 DATA ANALYSIS AND RESULTS OF THE RECOGNITION STUDY

The data were analyzed and sorted in “IBM SPSS 28” and “Excel”. The statistical model used to analyze the data was binary logistic regression.

4.1 Demographics

There were 275 participants who joined the study. Among them, 193 people had no prior animation experience, 78 people had a little bit animation experience, and 4 people had a lot of animation experience. Within all the participants, 207 are male, 64 are female, and 4 are non-binary/unwilling to tell. All participants took same test at each group.

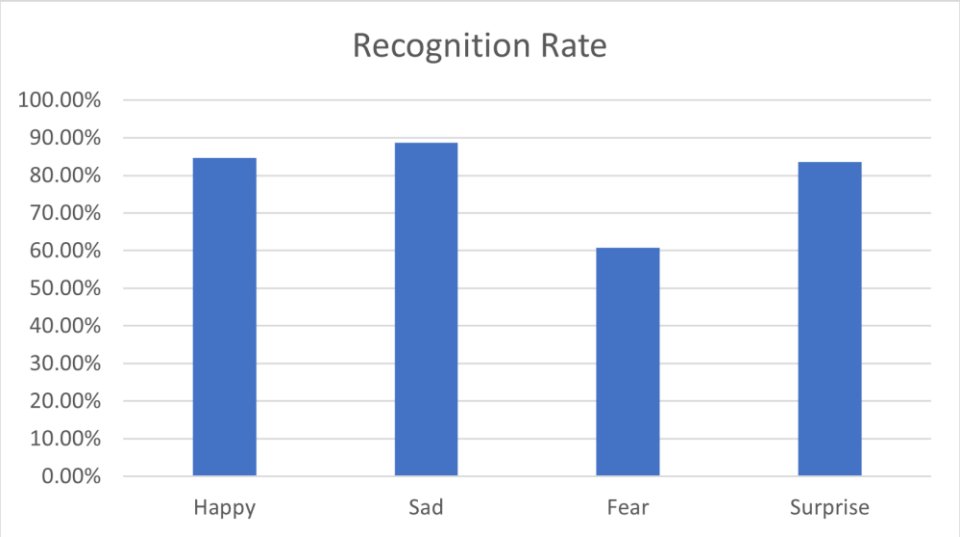
4.2 Results of the Recognition Study

All the participants answered each question by selecting the correct emotion that they believe the character was expressing.

4.2.1 Results of the Micro-Expressions’ recognition on the Stylized Character

The mean of the recognition for 4 micro-expressions of the stylized character was 79.45% (happy = 84.73%; sad = 88.73%; fear = 60.73%; surprise = 83.64%). The overall mean recognition rate was > the baseline acceptable rate, which is 60% and the mean recognition rate of each individual emotion was also > 60%. The result of the recognition of micro-expressions’ recognition on the stylized character is shown in figure 4.1.

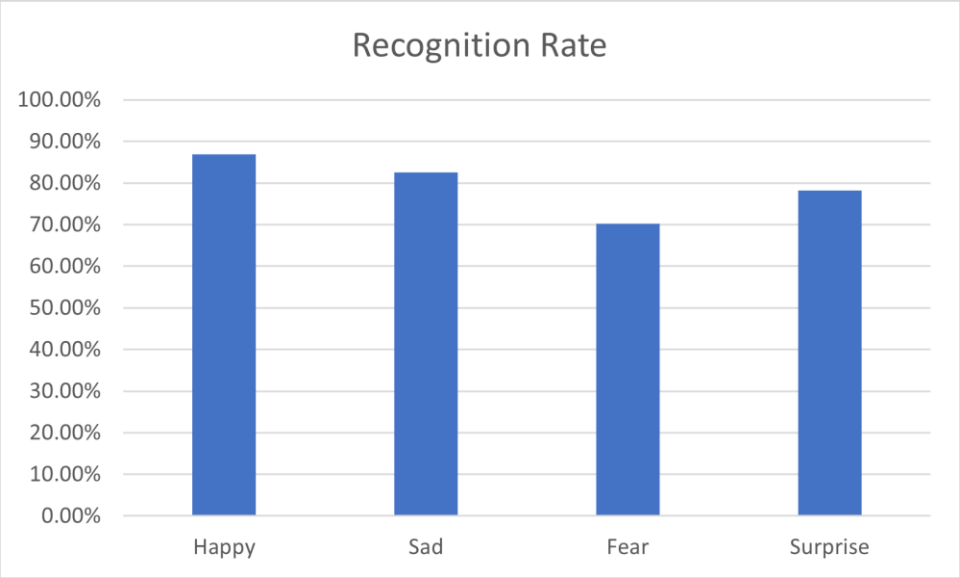
Table 4.1 Data Analysis of the Micro-Expression's Recognition on the Stylized Character



4.2.2 Results of the Micro-Expression's recognition on the Realistic Character

The mean of the recognition for 4 micro-expressions of the realistic character was 79.27% (happy = 87.37%; sad = 82.94%; fear = 69.62%; surprise = 77.13%). The overall mean recognition rate was > the baseline acceptable rate, which is 60% and mean recognition rate of each individual emotion was also > 60%. The result of the recognition of micro-expressions' recognition on the realistic character is shown in figure 4.2

Table 4.2 Data Analysis of the Micro-Expression's Recognition on the Realistic Character



4.2.3 Effects of independent variables on the "recognition of micro-expressions"

The data was collected from 275 participants. The researcher used binary logistic regression for analyzing the effect of each independent variable on the recognition of micro-expression (1 represents "recognized", 0 represents "not recognized"). Table 4.3 and 4.4 showed the fixed effects results and fixed coefficients results (significance level at 0.05).

Table 4.3 Binary Logistic Regression Fixed Effects Results on **Recognition of Micro-Expressions**

Fixed Effects[a]

Source	F	df1	df2	Sig.
Corrected Model	12.192	8	2191	0.000
style	0.000	1	2191	1.000
gender	4.712	2	2191	0.009
animationexperience	0.638	2	2191	0.528
Emotion	29.720	3	2191	0.000

Probability distribution: Binomial

a. Target: Recognition

Table 4.4 Binary Logistic Variables in the Equation Results

Variables in the Equation

		B	S.E.	Wald	df	Sig.
Step 1[a]	gender=Non-binary/unwilling to tell			8.811	2	0.012
	gender=Male	0.687	0.398	2.980	1	0.084
	gender=Female	0.370	0.406	0.829	1	0.363
	Emotion=Surprise			89.076	3	0.000
	Emotion=Happy	0.358	0.164	4.768	1	0.029
	Emotion=Sad	0.343	0.163	4.404	1	0.036
	Emotion=Fear	-0.809	0.141	32.874	1	0.000
	Constant	0.492	0.587	0.702	1	0.402

a. Variable(s) entered on step 1: style, gender, animationexperience, Emotion.

Based on the data analysis, the effect of **visual style** was not significant on **micro-expression's recognition**, (F (1,2191) = 0.000, p = 1). The stylized character had the exact same recognition rate as the realistic character.

For **emotion type**, significant effect was found on **recognition of micro-expressions** (F(3,2196) = 32.407, p = 0.000). According to Table 4.4, significances were found in several factors. **Happy Emotion** (B = 0.358, S.E. = 0.164, p = 0.029), **Sad Emotion** (B = 0.343, S.E.= 0.163, p=0.036) were recognized significantly better than the **Surprise Emotion.** The **Surprise Emotion** was recognized significantly better than **Fear Emotion** (B = -0.809, S.E. = 0.141, p = 0.000). Table 4.5 showed the descriptive statistics.

Table 4.5 Descriptive Statistics on the factor **Emotion**

Report

Recognition Rate

Emotion	Mean	N	Std. Deviation
Happy	0.86	550	0.349
Sad	0.86	550	0.351
Fear	0.65	550	0.476
Surprise	0.81	550	0.393
Total	0.79	2200	0.404

In table 4.6, confusion matrix table was created for the recognition accuracy of micro-expressions.

Table 4.6 Confusion Matrix of Micro-Expression Recognition Accuracy Rate

Group 1	Happiness	Sadness	Fear	Surprise	Disgust	Anger	Neutral	Unable to recognize
Happiness	85.50%	1.50%	0.20%	0.20%	0.20%	1%	10.20%	1.50%
Sadness	0.30%	85.80%	0.90%	0.90%	4.40%	0.90%	3.80%	2.90%
Fear	0.20%	0.70%	65.80%	17.50%	14.50%	0.50%	0.20%	0.50%
Surprise	0%	0.40%	12%	80.50%	4%	2%	0.40%	0.70%

The researcher collected and analyzed the data of factor **gender (male/female/non-binary)**. Binary logistic regression table showed that the effect of **gender** was significant on **recognition of micro-expressions** ($F(2,2197) = 4.163$, $p = 0.016$). Table 4.4 showed that the non-binary group recognized the micro-expressions significantly worse than other participants.

Considering participants may have variety in animation experience time, which can be a potential factor affecting recognition of micro-expressions. The factor **participant's animation experience** was collected and analyzed during the study. Table 4.4 showed that the effect of **participant's animation experience** was not significant on **recognition of micro-expressions** ($F(2,2191) = 0.638$, $p = 0.528$).

4.3 Chapter Summary

This chapter describes the process of data analysis and collection for recognition study, provides the data of recognition study, explains the result based on the data analysis and explicates which emotions were validated and can be used for the emotion rating study.

CHAPTER 5 DATA ANALYSIS AND RESULTS OF THE EMOTION RATING STUDY

The statistical models used to analyze the data sets were binary logistic regression and linear mixed model. The data was sorted in Excel and then analyzed with IBM SPSS.

5.1 Results on the Variable "Emotion's Intensity Rating"

Since the emotion's intensity rating data was collected by 5-point Likert scale, the researcher used "Linear Mixed Model" to analyze the effect of each independent variable on **emotion's intensity rating**.

Table 5.1 Linear Mixed Model Results on **Emotion's Intensity Rating**

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	4390	3677.759	0.000
Gender	2	4390	2.114	0.121
AnimationExpereince	2	4390	46.648	<0.001
DegreeofMicroexpressions	1	4390	16.570	<0.001
Style	1	4390	66.538	<0.001
Emotion	3	4390	304.058	<0.001

a. Dependent Variable: Intensity.

Table 5.1 showed that the effect of **animation experience** ($F(2,4390) = 46.648$, $p < 0.001$), **degree of micro-expressions** ($F(1,4390) = 16.570$, $p < 0.001$), **character visual style** ($F(1,4390) = 66.538$, $p<0.001$) and **emotion type** ($F(3,4390) = 304.058$, $p<0.001$) was significant on **emotion's intensity rating**. However, **gender** ($F(2,4390) = 2.114$, $p = 0.121$) did not have significant effect on **emotion's intensity rating**.

Table 5.2 showed the estimates of fixed effects results. For **animation experience**, the participants with a lot of animation experience rated the emotion's intensity significantly higher than other participants. For **degree of micro-expressions**, the non-exaggerated micro-expressions group had significantly lower intensity rating than the exaggerated micro-expressions group. For **character visual style**, the realistic character was rated with significantly higher intensity than the

stylized character. For **emotion type**, the happy group and the sad group were rated with significantly lower intensity than the surprise group.

Table 5.2 Estimates of Fixed Effects Results on **Emotion's Intensity Rating**

Estimates of Fixed Effects[a]

Parameter	Estimate	Std. Error	df	t	Sig.
Intercept	4.766	0.174	4390.000	27.453	<0.001
AE = No prior animation experience	-0.999	0.121	4390.000	-8.226	<0.001
AE = A little animation experience	-1.142	0.123	4390.000	-9.262	<0.001
AE = A lot of animation experience	0[b]	0.000			
DOM = Non-exaggerated micro-expressions	-0.118	0.029	4390.000	-4.071	<0.001
DOM = Exaggerated micro-expressions	0[b]	0.000			
Style = Stylized	-0.236	0.029	4390.000	-8.157	<0.001
Style = Realistic	0[b]	0.000			
Emotion = Happy	-0.861	0.041	4390.000	-21.049	<0.001
Emotion = Sad	-0.952	0.041	4390.000	-23.272	<0.001
Emotion = Fear	-0.074	0.041	4390.000	-1.800	0.072
Emotion = Surprise	0[b]	0.000			

a. Dependent Variable: Intensity.

b. This parameter is set to zero because it is redundant.

5.2 Results on the Variable "Emotion's Naturalness Rating"

Since the emotion's naturalness rating data was collected by 5-point Likert scale, the researcher used "Linear Mixed Model" to analyze the effect of each independent variable on **emotion's naturalness rating**.

Table 5.3 Linear Mixed Model Results on **Emotion's Naturalness Rating**

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	4390	2584.418	0.000
Gender	2	4390	0.676	0.509
AnimationExpereince	2	4390	17.207	<0.001
DegreeofMicroexpressions	1	4390	5.068	0.024
Style	1	4390	1.331	0.249
Emotion	3	4390	14.150	<0.001

a. Dependent Variable: Naturalness.

Table 5.3 showed that the effect of **animation experience** ($F(2,4390) = 17.2$, $p < 0.001$), **degree of micro-expressions** ($F(1,4390) = 5.068$, $p<0.001$) and **emotion type** ($F(3,4390) = 14.150$, $p<0.001$) was significant on the variable **emotion's naturalness rating**. However, there was no significant effect of **gender** ($F(2,4390) = 0.676$, $p = 0.509$) and **character visual style** ($F(1,4390) = 1.331$, $p = 0.249$) on the variable **emotion's naturalness rating**.

Table 5.4 showed the estimates of fixed effects results. For **animation experience**, the participants with a lot of animation experience rated the emotions with significantly higher naturalness than other participants. For **degree of micro-expressions**, the exaggerated micro-expressions group was rated as significantly lower natural than non-exaggerated micro-expressions group. For **emotion type**, the happy group and the fear group were rated significantly higher than the surprise group.

Table 5.4 Estimates of Fixed Effects Results on **Emotion's Naturalness Rating**

Estimates of Fixed Effects[a]

Parameter	Estimate	Std. Error	df	t	Sig.
Intercept	3.552	0.194	4390.000	18.317	0.000
AE = No prior animation experience	-0.603	0.136	4390.000	-4.445	0.000
AE = A little animation experience	-0.729	0.138	4390.000	-5.290	0.000
AE = A lot of animation experience	0[b]	0.000			
DOM = Non-exaggerated micro-expressions	0.073	0.032	4390.000	2.251	0.024
DOM = Exaggerated micro-expressions	0[b]	0.000			
Emotion = Happy	0.206	0.046	4390.000	4.517	0.000
Emotion = Sad	-0.017	0.046	4390.000	-0.378	0.705
Emotion = Fear	0.196	0.046	4390.000	4.298	0.000
Emotion = Surprise	0[b]	0.000			

a. Dependent Variable: Naturalness.

b. This parameter is set to zero because it is redundant.

5.3 Result on the Variable "True Emotion Recognition"

Since the data of true emotion recognition was binary (0 = "not recognized" and 1 = "recognized"), the researcher used "Binary Logistic Regression" to analyze the effect of each independent variable on **true emotion recognition**.

Table 5.5 Binary Logistic Fixed Effects Results on the Variable **True Emotion Recognition**

Fixed Effects[a]

Source	F	df1	df2	Sig.
Corrected Model	23.580	9	4390	0.000
Gender	4.303	2	4390	0.014
AnimationExpereince	4.515	2	4390	0.011
Degree of Micro-expressions	114.396	1	4390	0.000
Character Visual Style	0.268	1	4390	0.605
Emotion Type	31.474	3	4390	0.000

Probability distribution: Binomial

a. Target: Recognition

Table 5.5 showed that the effect of **participant's gender** (F(2,4390) = 4.303, p = 0.014), **participant's animation experience** (F(2,4390) = 4.515, p = 0.011), **degree of micro-**

expressions (F(1,4390) = 114.396, p = 0.000) and **emotion type** (F(3,4390) = 31.474, p = 0.000) was significant on true emotion recognition. However, there was no significant effect of **character visual style** (F(1,4390) = 0.268, p =0.605) on **true emotion recognition**.

Table 5.6 showed the contribution of each independent variable to the model. For **participant's gender**, the male group (B=-0.617, S.E. = 0.268, p = 0.021) recognized the true emotion significantly worse than the non-binary/unwilling to tell group. For **participant's animation experience**, the non-animation experience group (B = -0.883, S.E. = 0.262, p = 0.001) and the a little bit animation experience group (B = -1.030, S.E. = 0.268, p = 0.000) recognized the true emotion significantly worse than the a lot of animation experience group. For **degree of micro-expressions**, the true emotions in the non-exaggerated micro-expression group (B = -0.744, S.E. = 0.070, p = 0.000) were recognized significantly worse than those in the exaggerated micro-expression group. For **emotion type,** the happy emotion group (B = -0.497, S.E. = 0.103, p = 0.000) was recognized significantly worse than the surprise emotion group. The sad emotion group (B = 0.453, S.E. = 0.093, p = 0.000) was recognized significantly better than the surprise emotion group.

Table 5.6 Binary Logistic Variables in the Equation Results

Variables in the Equation

		B	S.E.	Wald	df	Sig.
Step 1[a]	Gender = Non-binary/unwilling to tell			9.781	2	0.008
	Gender = Male	-0.617	0.268	5.322	1	0.021
	Gender = Female	-0.432	0.273	2.502	1	0.114
	AE= A lot of animation experience			15.990	2	0.000
	AE=No animation experience	-0.883	0.262	11.347	1	0.001
	AE= A little bit animation experience	-1.030	0.268	14.814	1	0.000
	DOM=Non exaggerated micro-expression	-0.744	0.070	113.727	1	0.000
	Emotion=Surprise			93.858	3	0.000
	Emotion=Happy	-0.497	0.103	23.445	1	0.000
	Emotion=Sad	0.453	0.093	23.733	1	0.000
	Emotion=Fear	-0.080	0.097	0.679	1	0.410
	Constant	0.870	0.380	5.250	1	0.022

a. Variable(s) entered on step 1: Gender, AnimationExpereince, DegreeofMicroexpressions, Style, Emotion.

CHAPTER 6 DISCUSSION AND CONCLUSION

This chapter provides a discussion of the research findings based on the data analysis conducted in the previous chapter and states the conclusion of the research.

6.1 Discussions of the Findings

6.1.1 Findings of the Factor "Degree of Exaggeration of Micro-expression"

For **degree of exaggeration of micro-expression**, there was significance found on emotion's **intensity rating**, **naturalness rating**, and **true emotion recognition**. One of the main goals of this research was to examine the extent to which the degree of exaggeration of micro-expression affects the intensity and naturalness of animated character's emotion. Below is the hypothesis of this research question.

- **H0**: The exaggerated micro-expressions do not affect the perceived naturalness and intensity of 3D animated character's emotion.
- **H1**: The exaggerated micro-expressions affect the perceived naturalness and intensity of 3D animated character's emotion.

Based on the data analysis mentioned in the previous chapter, the researcher rejected the null hypothesis.

For **intensity rating**, the normal micro-expression group was rated significantly lower than the exaggerated micro-expression group. The possible reason could be that the amplified facial action unit's motion created a huge contrast between neutral face and emotional face and caused the emotional face to be more intense. There was a similar result from previous research lead by Cezary Biele & Anna Grabowska. In accordance with their research, the dynamic facial expressions (animations) were rated as more intense than still facial expressions (image with emotional face). And it was because that the dynamic facial expressions had contrast between neutral face and emotional face, while static facial expressions had no contrast. In addition, Pollick et al. (2003) tested the influence of exaggerated point-light facial motion on the recognition of emotion and emotion intensity rating. They reported that exaggerated point-light facial motion increased the emotion intensity rating. Therefore, it can be concluded that the emotion displayed

by exaggerated micro-expression is more intense than the emotion displayed by normal micro-expression.

For **naturalness rating**, the normal micro-expression group was rated significantly higher than the exaggerated micro-expression group. The possible reason was that the amplified facial action unit's motions may have caused the participants to perceive the emotion as not realistic/natural. This finding is in alignment with prior research. Hyde et al. (2014) tested the effect of magnitude of facial motion on the emotion naturalness. They reported that there was a negative relationship between the magnitude of facial motion and emotion naturalness, which meant the exaggerated facial expression became less natural than normal facial expression and damped expression. Therefore, the researcher concluded that the rating of emotion naturalness decreases when the degree of exaggeration of micro-expression increases.

For **true emotion recognition**, the participants recognized the true emotion of the 3D animated character with the combination of macro-expression plus exaggerated micro-expression significantly better than the combination of macro-expression plus normal micro-expression. The possible reason was that the magnified motion of facial micro-expression was more obvious to the viewer. Moreover, the hidden emotion expressed by exaggerated micro-expression was easier to be felt by audiences than the normal micro-expression. A similar result was found by a research group from the University of California, Riverside. Kumar et al. (2019) reported that facial micro-expression from a real person avatar image with motion magnified emotion can be classified by Convolutional Neural Network better into three different groups (Negative, Positive and Surprise). Moreover, Hess et al. (1997) reported that exaggeration of facial expressions increased the emotion recognition rate. Therefore, it can be concluded that the exaggeration of micro-expression increased the recognition accuracy of avatar's emotion.

6.1.2 Findings of the Factor "Visual Style"

For **character visual style**, no significant effect was found on the variable **emotion naturalness rating**, **recognition of micro-expression** and **true emotion recognition**. However, the researcher did find significance of **visual style** on the variable **intensity rating**, which partially answered RQ4 - To what extent does the visual style of 3D animated character affect the perceived naturalness and intensity of the animated character's emotion?

For **intensity rating**, the stylized character was rated significantly lower than the realistic character. This might be due to the fact that the stylized character is lacking facial details compare to the realistic character and therefore facial deformations appear more intense on the realistic character because of its own design, even if the two characters use same skeleton deformation system and the same magnitude of facial displacement. A study by Courgeon et al. (2009) tested the effect of facial wrinkles with different rendering style on the perception of facial emotions. They reported that realistic rendering wrinkles were recognized as more expressive. Though the researcher didn't find direct relation between the intensity and expressiveness of emotion, it can be the potential reason for this finding. Further work will need to be conducted to find the relationship between emotion intensity and expressiveness.

6.1.3 Findings of the Factor "Emotion Type"

For **emotion type**, the significant effect was found on the variable **recognition of micro-expression**, **naturalness rating**, **intensity rating** and **true emotion recognition**.

For **recognition of micro-expression**, the happy group, sad group, and surprise group were recognized significantly better than fear group. The possible reason for this was that the dominating AUs for happy (AU12), sad (AU1 + AU4 + AU15 | AU11), and surprise (AU1 + AU2 | AU5) were easier to recognize than fear (AU1 + AU2 + AU4). The dominating AUs for each emotion were defined by Lucey et al. in 2010. According to Tian et al. (2001), the AUs located on the lower part of the face had significant better recognition accuracies than the AUs located at upper part of the face. Therefore, it can be concluded that the micro-expressions with dominating AUs which are mainly located at lower part of the face are recognized significantly better than the micro-expressions with dominating AUs which are mainly located at upper part of the face.

For **intensity rating**, the surprise emotion group was rated significantly higher than the happy emotion group and sad emotion group. Because each emotion group contained two emotions (happy + sad; sad + happy; surprise + fear; fear + surprise). The possible reason for this was that surprise had more dominating AUs than happy and sad.

For **naturalness rating**, the happy emotion group and fear emotion group were rated significantly higher than the surprise emotion group. According to prior research lead by Sato & Yoshikawa in 2004, when the velocity was at 40ms/frame which was really close to the velocity in this research, fear was rated with significant higher naturalness rating than other emotions (Sato

& Yoshikawa, 2004). The potential reason for high naturalness rating in happy emotion group in this research was that the researcher added three more secondary AUs for happiness to support the dominating AU, which might cause the emotion to be more natural.

For **true emotion recognition**, the sad emotion group, and the surprise emotion group were recognized significantly better than the happy emotion group. The potential reason for this was that the concealed happiness was not easy to recognize when the fake (main) emotion was sadness.

6.1.4 Findings of the Factor "Participant's Gender"

While gender did not have a significant effect on **intensity rating** and **naturalness rating.** It had significant impact on **recognition of micro-expressions** and **true emotion recognition**.

For **recognition of micro-expressions**, the non-binary/unwilling to tell group recognized the micro-expressions significantly worse than other participants.

For **true emotion recognition**, the non-binary/unwilling to tell group recognized the true emotion significantly better than the male group. However, these two findings were not generalized because the number of non-binary participants was low.

6.1.5 Findings of the Factor "Participant's Animation Experience"

A significant effect was found in **animation experience** on the variable **naturalness rating**, **intensity rating**, and **true emotion recognition**.

For **naturalness rating**, the lot of animation experience group rated the emotion's intensity significantly higher than the other participants.

For **intensity rating**, the lot of animation experience group rated the emotion's naturalness significantly higher than the other participants.

For **true emotion recognition**, the lot of animation experience group recognized the true emotion significantly better than the non-animation experience group and the little animation experience group.

To the best of the researcher knowledge, there was no prior study that collected and analyzed **animation experience** as independent variable. Based on all these three variables above, the participants with lot of animation experience rated naturalness and intensity of emotion significantly higher and recognized true emotion significantly better than the other two groups'

participants. The possible reason for this might be that the participants with a lot of animation experience can obverse the animation principles applied in the animation better than other participants and paid more attention to the animations than other participants because of better visual acumen.

6.2 Conclusion

One main finding of this research is that people can recognize micro-expressions in animated characters with a high degree of accuracy. A second important finding is that while exaggerating the micro-expressions improves recognition and perceived intensity of the character's emotion, it decreases perceived naturalness. A third important finding is that while **character visual style** does not seem to have a significant effect on **recognition of micro-expressions** and on **emotion's naturalness rating**, it seems to have a significant impact on perceived **intensity**. The data analysis results shows that the emotions expressed by stylized character are perceived as significantly less intense than those conveyed by the realistic character. The fourth finding is that, for the factor **emotion** has significant effect on the variable **recognition of micro-expressions**, **emotion's naturalness rating**, **emotion's intensity rating**, and **true emotion recognition**. Based on the data analysis results, the micro-expression is recognized significantly more accurate with happy emotion, sad emotion, surprise emotion than fear emotion. The fifth finding is that **gender** has significant effect on the variable **recognition of micro-expressions** and **true emotion recognition**. The data analysis results suggests that male and female recognize micro-expressions significantly better than non-binary participants, and the non-binary participants recognize the true emotion significantly better than male. The last finding is that **animation experience** has significant effect on **emotion's naturalness rating**, **emotion's intensity rating**, and **true emotion recognition**. Based on the data analysis results, the participants with a lot of animation experience rate the emotion's naturalness and intensity significantly higher than other participants and recognize the true emotion significantly better than other participants.

6.3 Limitations

As was mentioned in Chapter 1, two limitations were pointed out during the research. One was that the participants may exposed in different environments, which may influence the results of the study. Another limitation was that the participants may not pay enough attention to the animations and introductions (especially in emotion rating study). The lack of attention may cause the participants do not completely understand the structure of animations and ignored the micro-expression's existence which may cause biased data.

6.4 Future Work

The study included a relatively homogenous group of participants regarding gender, educational background (most participants are undergraduate students from Purdue University with major of Engineering). In the future, it is recommended to perform additional studies with wider range of subjects for investigating how the degree of micro-expression's exaggeration and character visual style is compensated by age, gender, educational background etc.

Another recommendation is to have a better animation structure in the future to help the participants paying more attention to the animations. For example, adding an attractive but short scenario at the very beginning of the animation (man accidently falls on the ground and then shows the facial expression with close up shot).

The study showed some values in micro-expression recognition, emotion rating, and concealed emotion recognition. It is recommended that perform this type of research into different subjects and emotions to validate the findings.

APPENDIX: QUESTIONNAIRE

Questionnaire for micro-expressions recognition study

- Recognition of micro-expressions.
    1. What emotion do you think the character is expressing?

Questionnaire for emotion rating study (Always rated from 1-5, 1 being low and 5 being high)

- Recognition of true emotion
    2. What emotion do you think the character is truly feeling?
- Emotion's intensity rating
    3. The magnitude and strength of the emotion.
- Emotion's naturalness rating
    4. How realistic/natural is the emotion expressed by the character?

Link of the stimuli animations[2]

[2] https://purdue.ca1.qualtrics.com/jfe/form/SV_6mpCSL06pPfnyqG

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